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ABSTRACT

This book presents information on career opportunities in mechanical engineering. Chapter 1 describes the historical development of mechanical engineering and its interactions with society, considers the growth of the American Society of Mechanical Engineers, and discusses the relevance of mechanical engineering to present-day and future society. Chapter 2 covers the spectrum of careers available including research, consulting, teaching, development, design, production, sales, law, the military, and politics. Personal requirements are presented in the form of a checklist of skills and interests in chapter 3. The amount of educational background needed for employment at various levels (technician, professional), and several interdisciplinary combinations including engineering/Master of Business Administration and engineering/Law are described in chapter 4. In chapter 5, the college selection process, work-study programs, and part-time jobs are discussed. Chapter 6 assesses opportunities for women, including a comparison of pay. A report, "Minorities in Engineering," by the Planning Commission for Expanding Minorities Opportunities, is the topic of chapter 7. The process of industrial recruitment of graduating seniors is discussed step-by-step in chapter 8. Demand for engineering and salaries of beginning graduates are also considered. Chapter 9 analyzes career development/advancement and lists professional mechanical engineering societies. An appendix lists schools offering accredited undergraduate curricula. (JM)

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OPPORTUNITIES IN **MECHANICAL ENGINEERING**

Seichi Konzo
James W. Bayne

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ABOUT THE AUTHORS

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Professor Konzo is a Fellow of the American Society of Heating, Refrigerating, and Air Conditioning Engineers, who have honored him with the E. K. Campbell Award for teaching and the F. Paul Anderson Medal for his research and writing. He authored dozens of technical papers and engineering bulletins as well as four books in his special field. In 1975 the University of Engineering College of Engineering presented him with an Alumni Honor Award for Distinguished Service in Engineering. He held memberships in A.S.M.E.,

A.S.E.E., Tau Beta Pi, Sigma Xi, Pi Tau Sigma, and Triangle fraternity before his retirement. He is currently serving as volunteer Consultant for the Small Homes Council-Building Research Council on the University of Illinois campus.

James W. Bayne, is Professor of Mechanical Engineering and Associate Head of the Mechanical and Industrial Engineering Department at the University of Illinois, Urbana-Champaign campus, and is in charge of academic advising for all Mechanical Engineering undergraduate students on the campus. He was born in Baltimore and raised in Cleveland, Ohio and received his B. S. degree in Mechanical Engineering at the University of Illinois in 1946 as a Navy V-12 student during World War II. After his military service he returned to the Illinois campus in 1946 as an Instructor and obtained his Master of Science degree in Mechanical Engineering in 1951. He has risen through all the ranks and was appointed Professor in 1968.

For many years he has served as a National Officer of Pi Tau Sigma, national Mechanical Engineering Honor Society. He was National Secretary for 12 years and National President for a three-year term. He has been in close touch with engineering educators at all 108 of the major schools where Pi Tau Sigma chapters are located. During his 15 years as an officer in Pi Tau Sigma he represented them on the National Council of the Association of College Honor Societies and was President of the Association in 1973 and 1974. He is a member of A.S.M.E., A.S.E.E., Omicron Delta Kappa, and Tau Beta Pi, and is a registered professional engineer in Illinois.

For a number of years he has been in charge of the advising of mechanical engineering students and each summer has worked with high school students on National Science Foundation and Junior Engineering Technical Society programs to introduce them to the field of Mechanical Engineering.

PREFACE*

Mechanical engineering is a profession. Its members do creative work that results in things that people need or want. These things may be automobiles or power lawn mowers, nuclear plants or air conditioning systems, rocket engines or interplanetary space vehicles. Mechanical engineers, while strongly oriented toward science, *are not scientists.*

Science is a search for knowledge. The science of mathematics extends abstract knowledge. The science of physics extends organized knowledge of the physical world. In each of these sciences, the scientist can concentrate on a carefully isolated aspect of reality.

The engineer must deal with reality in all its aspects. He must not only be competent to use the most classical and the most modern parts of science, but he must also be able to devise and make a product which will be used by people. Moreover, he must assume professional responsibility insofar as safety and wellbeing of people are affected by the thing he makes.

Specifically, mechanical engineering is the branch of engineering which studies the conversion of energy from one form to another, the design of all types of machines, the instrumentation and control of all types of physical processes, and the control of human and machine environments.

We have explained what a mechanical engineer is. Now let us examine briefly what he or she is not.

A mechanical engineer is not a mechanic, a technician, or a machinist. In the Department of Mechanical Engineering you will not be taught how to fix an automobile engine, run a lathe, or repair an air conditioning unit. You will learn the broad engineering science principles behind each of these devices. As a well-educated mechanical engineer, you will learn the basic fundamentals which do not change with time and upon which you will build your professional career.

Following graduation you will continue learning throughout your life—as any professional person must—but you will study materials which will add to your firm engineering science foundation.

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CONTENTS

About the Authors iii

Preface v

1. **The History of Mechanical Engineering** 1

   Olden days, Early British and American engineers, Engineering developments depend on each other, Subdivisions within mechanical engineering, Mechanical engineering and social relevance, The role of the engineer in the future.

2. **What Mechanical Engineers Do** 14

   Spectrum of career activities, The research engineer, The consultant engineer, The engineering teacher, The research and development engineer, Development that involves testing, Other development problems, The design engineer, Products that mechanical engineers design, The designer's procedures, The production engineer, The distribution engineer, The sales engineer, Manufacturer's representative, Mechanical engineers in law careers, Engineers in operations research fields, What about engineers in government? What about engineers in politics? What does a mechanical engineer do?

3. **Personal Requirements** 58

   A checklist for the high school student.

4. **What Educational Background Is Required?** 68

   The members of the engineering team, Technician back-

ground, Basic undergraduate training for engineering, What about newer interdisciplinary studies? Combined liberal arts—engineering programs, What about graduate study? Mechanical engineers with MBA degrees, Mechanical engineers with law degrees, Predictions for graduates in 1980s.

5. **How to Select a College** 82

Should you go to a community college or an accredited college? What about a large school or a small school? What about ACT or SAT scores and rank in class? First step for application, When to start the process, What about costs? What are cooperative work-study programs? What about part-time jobs on campus? What about summer jobs? Factors in choosing a college, Selecting more than one school, When can you expect a reply? Finalizing the application.

6. **Opportunities for Women** 93

Before 1970, The 1970s—The transition decade, Are women engineers paid as much as men? What do women engineers do in their occupations? How far can women engineers rise in their profession? Marriage, children, and family, What about the future?

7. **Opportunities for Racial Minorities** 105

Who are the minorities? Why the emphasis on engineering? How do the minorities fare now? When does career selection begin? What should the colleges do to retain engineering students? How do the commission's findings relate to minority students?

8. **How Does One Get Started?** 113

Recruitment of graduating seniors, The seasoned engineer seeks a position, What company personnel people look for, Where graduates go, Job satisfaction, Peaks and valleys in demand for engineers and scientists, Salaries of beginning graduates.

9. What Are the Prospects for Advancement? 132

Grading continues after school, The first job may not be the only job, The management team, What about financial rewards? Know them by the company they keep, Societies of interest to all engineers, Does the engineer have a code of ethics?

Appendix. Schools Offering Accredited Undergraduate Curricula in Mechanical Engineering 145

CHAPTER 1

THE HISTORY OF MECHANICAL ENGINEERING

OLDEN DAYS

In days of old there were engineers, but they were not called by that name. The ancient Egyptians who built the pyramids were supposed to have utilized inclined planes, levers, pulleys, rollers, and other force-magnifying devices to transport the heavy stones. Engineering was also involved in the building of large ships, the piling up of rocks to build aqueducts and cathedrals, as well as destructive devices for battering the walls of ancient cities. Two prominent names from history (Archimedes and Leonardo da Vinci) are mentioned as early "engineers," although they were regarded as artists, craftsmen, and "scientists" also. Engineering was not a separate discipline until fairly recently.

In the 18th century, the pot began to boil. The Industrial Revolution started when many ingenious and inventive souls began to use natural forces to replace human and animal muscle power. In the beginning, there were military engineers who designed devices for battering walls or shooting cannon balls. Other military engineers designed portable bridges, highways, ships, and a host of equipment to move an army or a navy.

The first departure from military engineering came when a group of engineers devoted their talents in developing non-military devices such as highways, bridges, aqueducts, cathedrals, monasteries, castles, and palaces. These engineers were designated as "civil" engineers, because their attention was focused on civil rather than military matters.

Much later, and especially in the 19th Century, such inventions as the steam engine, cotton gin, steam locomotives, and weaving mills required more than blacksmiths and millwrights to design and build them. These new devices involved movements of pistons, shafts, gears, belts, and cams, and a new type of engineer emerged. The mechanical engineer was born in the Industrial Revolution during which factories replaced the cottage industries. Much later, and mainly in the 20th century, separate branches of engineering began to sprout in fertile soil. Among these were: electrical engineering, electronics engineering, aeronautical engineering, astronautical engineering, nuclear engineering, computer engineering, etc.

In engineering circles, brief one-sentence descriptions of the various branches of engineering run as follows:

"If you can't see it, its electrical engineering,
If you can dig it, it's mining engineering,
If you can smell it, it's chemical engineering,
If it doesn't move, it's civil engineering, and
If it moves, it's mechanical engineering."

EARLY BRITISH AND AMERICAN ENGINEERS

If you will look up the name of James Watt in an encyclopedia, you will read about the accomplishments of this Scottish engineer, who designed and developed the reciprocating steam engine. The expansion powers of steam were utilized to move a piston back and forth inside of a cylinder. Then, by clever energy transmitting devices, a pulley was turned. Thus, the overshot water wheel and the mule-powered wheel were replaced by a more reliable source that could be more easily controlled. The spread of the new steam engine took different paths in England and in the Americas. The British were interested in engines to run their textile and iron industries. The Americans were interested at first in mechanical transportation, both on water and on land. Robert Fulton and John Stevens worked to develop steamboats which enabled goods to be moved upstream. Peter Cooper and Mathias William Baldwin developed the locomotive, which was responsible for the opening of the West, and replaced

horse-driven wagons and coaches.

Other great leaders in the American Industrial Revolution included Eli Whitney, with his cotton gin that established the American textile industry; Francis A. Pratt, David Brown, and Lucian Sharpe with their measuring devices; George Corliss with his advances in steam engines; Henry Worthington who developed a portable pump; and Stephen Wilcox and George H. Babcock who made significant developments in the water-tube boiler. We must not forget the major contribution of Eli Whitney in the area of standardization of machine parts which made it possible to interchange component pieces—this was the basic requirement for a successful assembly line in a production factory. This concentration of attention on American and British engineers does not mean that the rest of the world was sleeping. Many mechanical engineering developments were taking place in Germany and other parts of Europe—in fact a real ferment was taking place in many parts of the world.

ENGINEERING DEVELOPMENTS DEPEND ON EACH OTHER

We do not wish to imply that engineering developments were only along mechanical lines. Far from it. During this same era the discoveries and developments of Alexander Graham Bell and Thomas Edison brought forth the skyrocketing development of electrical engineering. These are not self-contained improvements, but intertwining and related developments. For example, electrical generators could be turned by a water wheel, and this in turn led to a fascinating series of developments of both low-head and high-head water wheels. The low-head water wheels, found on some of our largest hydro-electric projects in the West, are gigantic pieces of slow-moving machinery. On the other hand, the high-head water wheels installed in some California stations spin the wheels at tremendous speeds. Similarly, the use of steam for electrical power generation started with slow-moving reciprocating engines, but then moved towards high-speed steam turbines considerably smaller in size than the slow steam engines of the early 20th century. Our point

is that electrical engineering was able to move ahead because of simultaneous developments in mechanical engineering, and vice versa. Mechanical engineering in turn depended upon the advances made in metallurgical engineering. For example, the modern gas turbine that moves jet aircraft would not be possible without metal alloys that were unheard of in 1930.

SUBDIVISIONS WITHIN MECHANICAL ENGINEERING

A good measure of the growth of interest in mechanical engineering in the last 90 years is indicated by the history of the American Society of Mechanical Engineers. The A.S.M.E. was founded in 1880 by Robert Henry Thurston, its first president, who had taught both at Cornell University and Stevens Institute of Technology. Today A.S.M.E. has grown to a total membership of over 60,000 engineers and is subdivided into 24 technical divisions. The titles of these subdivisions are an indication of the breadth of coverage of mechanical engineers. These are:

- Air Pollution Control
- Applied Mechanics
- Automatic Control
- Biomechanical and Human Factors
- Design Engineering
- Diesel and Gas Engine Power
- Energetics
- Fluids Engineering
- Fuels
- Gas Turbine
- Heat Transfer
- Incineration
- Lubrication
- Materials Handling
- Metals Engineering
- Nuclear Engineering
- Petroleum Engineering
- Power Plant Engineering
- Pressure Vessel and Piping
- Railroad, Aviation and Space
- Rubber and Plastics
- Solar Energy Application
- Textile Engineering
- Underwater Technology

Besides having a leading role in the development of the steamship and railroads, mechanical engineers have made contributions to the advancement of the automotive industry, the airplane, machine tools, chemical and food processing, metal processing, household appliances, and many other items—particularly recent space efforts.

The key problems in the areas of heat transfer, fluid dynamics, reliability in design, developments in metals and other materials are typical of those handled by mechanical engineers.

Mechanical engineers hold a unique position in the engineering field in that they design, develop, and produce many of the tools required by other engineers. For example, the large antennas that scan the sky are built for the electronics engineer; huge earth moving equipment, concrete weighing and mixing machines, and giant hoisting cranes are constructed for the civil engineer; automatic digging machines for coal and ore are built for the mining engineer; pumps and vessels that hold liquid and gases at extremely high pressures are designed and built for the chemical engineer; delicate and reliable equipment is developed for the bioengineer; and burners, furnaces, and conveyors are designed for the metallurgical engineer. Hence, as new industries and new branches of engineering develop, there will always be a need for mechanical engineers.

MECHANICAL ENGINEERING AND SOCIAL RELEVANCE

The beginning of the 1970 decade has brought a new dimension to the mentality of young people—a desire of students to think things through, a need to weigh goals and objectives of careers and to decide for themselves whether their lives will be dedicated to relevant issues. Many engineering students have been caught in this swirl of self-examination and are asking such questions as: "Does a corporation have a soul?" "Does a corporation person have to conform to every part of corporation policy?" "Can an individual engineer have any influence on the policies of a company, especially if the policy seems to be contrary to his or her ideas?" "Does a corporation pay lip service to anti-pollution and continue to dump refuse and poisons into the streams and the atmosphere?" "Is planned obsolescence harmful to the national economy?" "Is overdesign of a part for perpetual life a waste of natural resources?" "How can an engineer, in his or her professional capacity, deal in socially relevant matters?"

Basically, the decision rests with the individual engineer. Just as there are doctors and lawyers who provide a socially relevant service and others who do not, so do engineers exist at both ends of the spectrum. Let us consider some professional opportunities open to a young mechanical engineer who is interested in solving some of the problems of society. Some of these examples are mentioned in other portions of this text, but the repetition is worthwhile if the social relevance of the problem is considered of utmost importance.

Air Pollution

The mechanical engineer is able to do something effective about clearing air pollution. These opportunities lie in new types of combustion engines, new fuels for existing internal combustion engines, reduction of sulphur from the fuel, precipitation of solid particles from combustion gases, and new approaches to power generation.

Thermal Pollution

Here again, the mechanical engineer is best equipped to cope with the complex problem of overheating of rivers and lakes from heated condenser water released from power-generating stations. Refrigeration machinery for producing summer air conditioning also requires tremendous amounts of water for cooling the hot refrigerant gases, so that thermal pollution of the atmosphere is a new problem of great importance.

Waste Products

The enormous quantities of waste material that must be disposed of from large communities each day need new approaches besides merely burying the refuse in a land fill or dumping it into the ocean. The recovery of heat from the combustion of waste products, the formation of combustible gas from organic matter, and the utilization of solid waste for building or road-making purposes are possible solutions if we are to avoid being buried in garbage and waste.

Recycling of Materials

The recovery of materials to be used again will become of increasing importance in the future, as natural resources diminish and the population increases. The recycling of glass bottles, whereby old bottles are melted down and formed into new bottles, is already being put into effect—as is the recovery of aluminum cans. Much more needs to be done to reduce the automobile junk heaps and to recover iron, aluminum, lead, and rubber from old cars. The recycling of paper is being carried out only in a few communities because of the high cost of reclaiming old paper.

Conservation of Resources

The mechanical engineer, more than any other engineer, can make substantial contributions towards the conservation of natural resources—some of which when used are gone forever. For example, in order to maintain homes, offices, and buildings at approximately 70 degrees Fahrenheit during the winter months, fuel is burned in a boiler or furnace—and eventually the heat generated is delivered to the building to offset the heat loss from the building through the windows, doors, walls, and ceiling. If the building is well-protected by storm windows, double-glass windows, storm doors, weatherstripping, insulation in walls and ceilings, and other energy-conserving devices, the quantity of fuel required for the season is below that of unprotected buildings. With few exceptions, improvements can be made to any type of building to reduce the heat loss from the building to the cold outdoors. Every gallon of fuel saved, every cubic foot of natural gas that is not required, means that much more available for future generations.

For the first time in history, some finite limits in fuel resources are beginning to show up. In the past, natural gas has been wasted and burned at the well heads as if the supply was unlimited. Today, many gas distribution companies are rationing their supply. Engineers will have to show architects the consequences of building designs which ignore insulation, use extensive roof surfaces, or overemphasize the use of glass windows.

Transportation Crisis

New transportation devices will require the best mechanical engineering brains for design and development. The bullet train in Japan, the world's fastest train, is primarily a mechanical engineering development. The future train, or vehicle, that will connect the main cities of the United States probably will not be a duplicate of present day trains, but will be specially designed. The present condition, where an air traveler spends two hours in the air to travel over 1,000 miles and then spends one hour at his destination to cover 15 miles between the airport and the city, is a good example of the need for the development of an airport-city vehicle of some sort—a bus on special bus lane, a monorail car, a subway train, or a nonstop express train between airport and a city terminal.

Housing Need

For the last several years the number 25,000,000 has been repeated again and again as a target—the claim is made that 25,000,000 housing units will have to be built in the United States by 1980 to handle the increase in population and to replace obsolete structures. Even if one places a conservative value of $10,000 per housing unit, the total cost can be seen as astronomical. This is a challenge for engineers as well as for mortgage bankers, real estate developers, architects, labor unions, code regulators, landscape and community planners, and builders. If a better design can be made at no increase in cost, if a better mechanical device can be developed to provide heating and cooling, if mass production techniques can be developed, the contribution will be substantial.

Water Utilization

In many manufacturing processes more water is used, by weight, than any other single substance. For example, in a paper mill tons of water are required for each ton of paper produced. The same is true in steel mills and in many other industrial organizations. The need for good-quality water continues to increase each year, and the

supply is limited. This means that water must be recycled and used over and over again before it is finally released to the oceans. Some of the urgent needs are for efficient water utilization, reclamation of water, prevention of water pollution, and desalination of water. Each of these problems demands engineering solutions—both mechanical and chemical in nature.

Fire Safety

Every time a fire occurs, a decrease in natural resources has taken place. The fire loss in the United States alone is a frightful drain on natural resources, and a variety of things should be done to reduce these losses. Warning systems that detect smoke, sprinkling systems that spread water on hot spots, fire-fighting equipment (including new types of sprays and nozzles), dampers that automatically close in ventilating systems, fire escape devices, and fire-resisting sprays and coatings are among the items that demand further attention and development.

Crime Prevention

The whole area of crime reduction and prevention is subject to inquiry by designers and engineers—including locks, storage vaults for valuables, remote inspection of property, warning devices against trespassers, fences and gates, and armored vehicles.

Noise Suppression

The public is aware of noise pollution, and manufacturers are including low-noise level as one desirable feature of their products. For example, an air-compressor manufacturer is designing quieter equipment for portable units; room air conditioners are being judged according to the noise produced within the room; automobile manufacturers are emphasizing quietness as a sales feature; and supersonic aircraft are being criticized for their noise and sonic boom.

Medical and Health Aspects

The whole field of bioengineering and biomechanics is a developing one. Surveys have shown that few medical practitioners have the desire to learn enough about engineering to become bioengineers; the burden has fallen on engineers to learn enough about physiology and medicine to enter this new field. Basically, the bioengineer becomes a member of a team that includes medical doctors and physiologists.

Food Production

As the world population continues to grow at an alarming rate, and with a finite land area for crop production, the problem of feeding the entire world becomes increasingly urgent. It can be solved by better machinery for planting and harvesting, better housing for animals (to increase their rate of production), increased utilization of desert and other less favorable areas, and exploration of ocean resources.

Product Safety

The Consumer's Product Safety Commission has become a potent force in shaping the design and production of consumer products, from children's toys to automobiles. This is an area that has not been emphasized by designers in the past, but which is now as important as performance. For example, you have seen press releases of manufacturers who have recalled cars with a possible faulty part, electric ovens that could emit harmful microwave radiation through leaky doors, electrical devices that could give a shock to the user, toys that have sharp edges, and lawn mowers that were not foolproof. The manufacturer and designer must protect themselves not only against normal responsible usage, but also against conditions over which they have little control. For example, the engineering designer must consider the hazards when an automobile collides with another auto or an immovable object. This has resulted in such devices as: neck rests, collapsible steering column, safety air bags, seat and shoulder

belts, safety bumpers, and a host of other items. These may not do much for the main function of the car, which is to provide transportation, but they are an attempt to insure that the function is completed without injury.

Although not related to product safety, the designer is also faced with the demands of the installer and service repairmen that the product be easy to assemble and easy to dismantle in case of needed repairs. Again such demands may have little to do with normal functioning of the device, but become most important when the device breaks down.

This list of items of relevancy can be extended indefinitely—in many cases, the survival of the human race is involved. There is no lack of urgent and relevant problems that need solution. What *is* needed is trained brainpower—mere talk about pollution and conservation is not sufficient—something positive has to be done soon. The engineer is in a particularly strong position to be doing something in these areas.

THE ROLE OF THE ENGINEER IN THE FUTURE

The case for the future role of the engineer was best expressed many years ago by Dr. Frank Aydelotte, former President of Swarthmore College, who edited a book, *English and Engineering.*

"A man will write crudely if his thinking is crude: there is no way in which an engineer can produce, in writing or speaking, the effect of an educated man unless he is educated; and, if one may take the word of the leaders in the profession, that part of his training which tends to humanize him, to develop him as a man, makes him to just that degree a better engineer."

"The engineer must deal with men as well as with machines. He must be able to think and to express himself in terms that other men will understand. He must be able to marshal and to arrange his thoughts about intricate and difficult matters so as to make them plain and clear and forcible. Eloquence in the old bombastic sense of the term is not demanded of him, but it is demanded that he have clearness and force and the ability to present a long and complicated

series of arguments, to weigh evidence on this side and that, and to come to a conclusion which will carry conviction.

"The engineer is destined to become an important figure, a leader, in the new age which is just now dawning. He cannot occupy a position of such importance without his heavy share of duties and responsibilities. He cannot be a leader without taking upon himself the task of solving many of the gravest problems of our civilization, human problems as well as mechanical, problems in finance, in government, in education, and in social life. The engineer must direct the labors of thousands of uneducated men, and he cannot escape some responsibility for their well-being. The work of his hands and brain may build up or destroy the welfare of whole industrial communities and of gigantic corporations. As an employer of younger engineers, he must take an active part in their education, that great part of education which comes when school days are over, and he may, if he has the wisdom, exercise a human influence more important than he can ever estimate. With such a role to play in the development of our civilization the engineer must think in terms of civilization, in human terms as well as material, or be a traitor to his opportunities."

The book in which the above quotation was printed was issued in the year 1917, more than a half-century ago. The remarks are more pertinent today than they were when first set down.

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CHAPTER 2

WHAT MECHANICAL ENGINEERS DO

Mechanical engineers help keep industrial production at high levels in the United States and throughout the world. The services rendered by graduates of mechanical engineering departments cover a broad spectrum—from scientific research to technical sales.

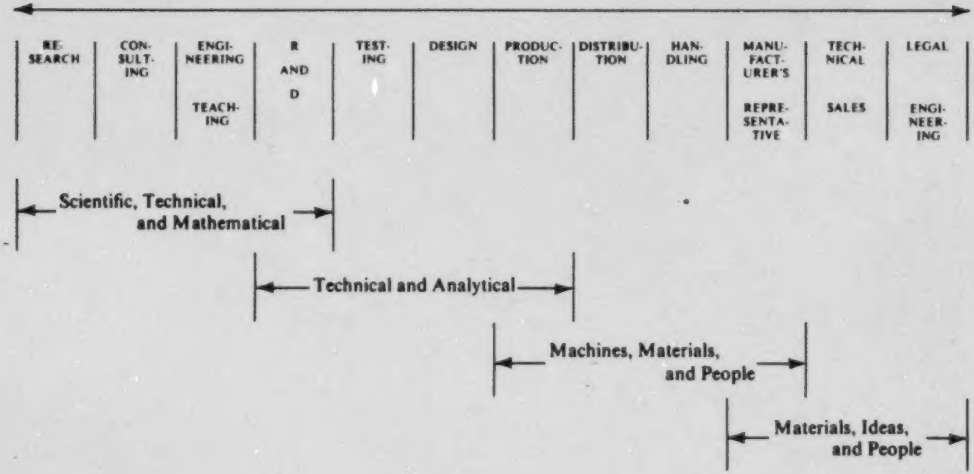
SPECTRUM OF CAREER ACTIVITIES

The chart (Fig. 2–1) shows a listing of the major components of mechanical engineering activities. This broad spectrum includes most of the types of work engaged in by engineers after graduation. In actual life, the graduate may shift from one activity to another. For example, a graduate may start his or her career in the production area—then be shifted to the design area—later to the testing department—and in some cases to technical sales. In small companies, one individual may handle several aspects of the business at the same time—as a designer, production supervisor, and testing engineer, all from the same desk.

As the spectrum indicates, different talents and interests are required in different parts of the same company. For example, at the left end of the spectrum, we find engineers who are science-oriented, technically competent, and mathematically gifted. In addition, both the consultant and the engineering teacher must be able to deal with people and have skills in communicating ideas.

At the righthand side of the spectrum, we find engineers who deal with materials, business matters, and people. Those involved as manufacturers' representatives, sales engineers, or with legal aspects

Figure 2-1. Spectrum of Activities Engaged in by Mechanical Engineers.



of engineering and business may not require the technical competence of a research engineer, but should be knowledgeable about business, accounting, economics, and people.

In a spectrum of this sort, there is no higher or lower order. The left side is no more preferred than the right side. Within each arbitrary division, there are engineers who are excellent, good, or fair, whether they are engineering teachers or production supervisors.

We are discussing activities engaged in by professional people, and usually there is no simple description of the work that an engineer assumes. For example, we could describe the main function of an engineer in a large organization as a "test engineer." The specific job in the plant may require that Diesel engines be tested for performance. The first job of the engineer may consist of observing and recording data of engines pulled from the assembly line and mounted on a test block. Later, he or she may test new models or a competitor's engines. The need to reduce air pollution requires that the same engineer become familiar with exhaust emissions and complicated chemical instrumentation. The continuing search for new alloys requires that the engineer become acquainted with alloying materials, heat treatment of metals, concentrated stresses, repeated stresses, and corrosion effects. There is no end to the knowledge and background information required of the plain "test engineer." Still later, he or she will know as much about acoustic measurements and noise abatement techniques as any engineer in a similar job. By this time, many years down the road, he or she is not only an "expert," but a true "professional," and management may recognize personal value by assigning additional titles, such as manager, director, or superintendent. Where he or she goes from the initial job as a "test engineer" depends upon the individual and, to some extent, upon "luck," which is another way of saying that the individual was not only at the right place at the right time, but was also prepared for new challenges.

With this background in mind, let us examine in some detail each segment of the career spectrum.

THE RESEARCH ENGINEER

What is research as it applies to mechanical engineering? Research is the discovery of something new. Research engineers are engaged in a host of activities. Here is a small sample:

Heat-resistant Steel

Mechanical engineers are seeking new alloys of steel, or combinations of exotic metals, that will permit higher operating temperatures to be maintained without loss of strength of the material. The alloys are tested for their ability to withstand stress, to resist corrosive action by gases and liquids, to bend without snapping, to stand heavy impact shocks without shattering, or to endure extremes of temperatures, both high and low. For example, theory indicates that the efficiency of a power plant electrical generating station will be increased if the steam supplied to the steam turbines is delivered at higher temperatures. This requires steel for boilers, piping, and turbines that can maintain their strength at temperatures so high that if they are not covered with insulation, the pipes and tubes carrying the steam would glow red. The blades on a steam turbine are not only being exposed to the blasts of high velocity steam but they are receiving these impacts many times per second for operating periods that may last years.

Medical Innovations

Mechanical engineers are developing new devices that serve medicine, such as artificial hearts, artificial kidneys, and artificial limbs, as well as mechanical probing devices that can be used by the surgeon to freeze small areas of tissue for surgery. Engineering researchers are seeking an understanding of the blood flow mechanism in that remarkable structure called the human body. From this knowledge might come someday a reliable improved artificial heart. Engineers working with medical teams have noted that persons suffering from cardiac difficulties have less stress imposed on the heart and lungs when the patient is placed in an air-conditioned intensive

care unit rather than in a hot hospital ward. Other research engineers are seeking materials for bone transplants that will not be rejected by the body; some are trying to understand the complicated mechanism of the arm-elbow-wrist-hand combination that is able to move in many directions without becoming disjointed. Out of such research might come better artificial limbs that might be controlled by muscular response. For example, if an artificial hand is to be exposed to corrosive atmosphere or high temperature, the design of the arm and its control present an interesting challenge to the engineer designer, who obtains insight from research. Research engineers, in cooperation with medical doctors, have developed remote monitoring and sensing devices for patients in intensive care wards. Constant measurements of vital functions are displayed on charts or viewing screens so that attendants can be made aware of changes in the pulse rate, heart action, temperature, or breathing rate.

Nuclear Power

Nuclear energy power requires better knowledge of the method by which heat is transferred to the gases that spin the turbines. In those nuclear plants utilizing heat transfer to water (or other fluids) from a high temperature tube, research engineers try to understand the manner in which bubbles form on the outside of the heated pipe. Or they may be concerned about the manner in which the flow of liquid occurs over the outside of the heated tube, knowing that if the tube is not cooled, a hot spot may develop on it that could lead to its failure.

Tire Improvements

Tire companies are seeking tires that are stronger, heat resistant, and skid resistant under a variety of road conditions. The research engineer may be concerned with the materials used in tire construction, in the manner of fabrication, or the very fundamental properties of fluids squeezed between the tire and the road surface. Such research could lead to machines that determine the properties of materials or to actual road testing of the vehicle.

Direct-energy Conversion

Theory indicates that electrical energy might someday be obtained directly from a high temperature plasma (or flame) without converting the heat from the energy-producing device to form steam. This short-cut process, referred to as direct-energy conversion, intrigues the research engineer because it promises the production of electricity without moving mechanical parts. On a small scale, one form of direct energy conversion, known as thermoelectricity, has been demonstrated as a practical device. The research that is needed is basically on materials, and the practical answer seems to be an elusive thing to capture.

Air Pollution

Air pollution is a many-faceted enemy of the environment that needs a multiple approach towards solution. Much research is being conducted on one phase of the air pollution problem, that involving automotive engines. Not only are new forms of internal combustion engines, refined exhaust systems, improved fuels, and catalytic converters being investigated, but so also are entirely new types of battery-powered vehicles and different combustion processes. In the case of power plants, heating plants, and waste incinerators, the research extends into such items as separation of sulphur from coal, the precipitation of soot and flyash particles from the gases that are emitted from the smokestack, the washing of the exhaust gases, and the use of devices called afterburners that consume the unburned combustible matter from a burner.

Desalination

Research in removing salt from sea water (desalination) has been extensive, since many areas have access to brackish water or sea water, but lack fresh water. This research involves such diverse topics as: intensity and duration of solar energy, transmission of solar energy through plastic films and glass, energy from nuclear power plants for distilling sea water, desalination by a freezing process,

water purification by chemical, ionization, and membrane processes, and the economics of large-scale desalination processes.

High-Speed Land Transportation

High-speed land transportation schemes involving vehicles introduce a host of problems that require research. For example, the decrease of friction will reduce wear of moving parts and lessen power requirements. Intensive research is being conducted on different types of bearings (such as ball bearings, roller bearings, journal bearings, and even air bearings) on different materials and on various lubricants under a wide variety of temperature and pressure conditions and chemical deteriorants. Furthermore, research is needed on aerodynamic wind resistance of different shapes, effects of vibrations, stability of the vehicle, effectiveness of brakes, and modes of control of the vehicle.

Supersonic Transports

Supersonic transports introduce a number of problems that need attack by research engineers. Included are those concerned with the impacts on the landing gear, mechanisms for variable wing movements, loading processes at airports, and noise reduction of jet engines—as well as reduction in pollution caused by improper combustion. A difficult problem connected with supersonic transports is the effect of high-flying aircraft on the ozone content of the stratosphere. Some claim that changes in the ozone content will affect the ultra-violet radiation reaching the earth, which in turn could affect the weather as well as the incidence of skin cancer.

Underwater Research

Research for underwater exploration and for undersea digging and mining involves not only problems of tremendous pressures but those of darkness. Hence, research on metals for high pressure loadings, seals for windows and ports, safety devices, underwater illumination, and effects on personnel is being conducted intensively.

Solar Energy Research

Research in this field has been in progress for more than half a century. Energy from the sun is available, especially in desert areas. Also, the technical equipment needed to convert solar radiation to heat is well known and available. The main obstacle to large-scale use of simple collecting and storage schemes lies in the initial cost of the installations. Research consists in seeking materials, methods, and ideas to lower costs to the point where the energy can become competitive with other energy sources.

More fundamental research must be done to find materials that will convert solar radiation directly into electrical energy. In the long run, this research may be more productive than the development of heat collectors.

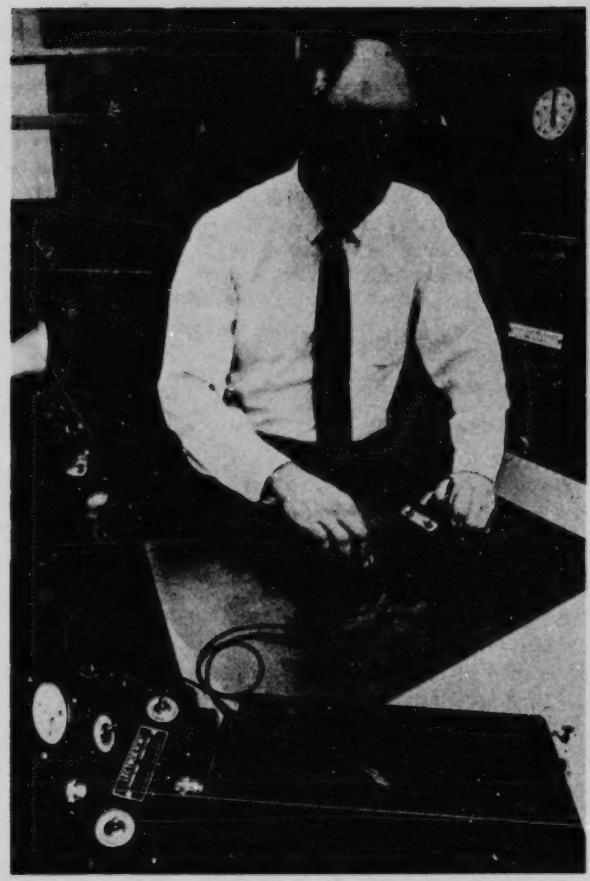
Energy from the Wind

The NASA has designed and built a large experimental windmill for generating electricity. Research is required to build a better airfoil or wind turbine that will provide for sudden gusts and overspeeds. Also required are effective storage devices for the electrical energy that is produced. The talents of engineers of many kinds will be needed.

The list of research problems is practically endless, since most larger firms and many smaller companies are devoting dollars and effort in attempts to seek new products, new applications, new techniques, and new procedures. The line dividing basic research from applied research is a thin one, and cannot always be sharply defined.

THE CONSULTANT ENGINEER

In many of the positions described in the succeeding sections, the mechanical engineer is involved as a corporation employee working for a large industrial firm. Opportunities for individual business ownership are available, but the path is difficult and requires two basic ingredients: (1) experience and (2) capital. Most of the recent engi-



Armco Steel Corporation

Mechanical engineering careers incorporate many related areas of knowledge. Here an engineer prepares electrochemical etchings to be used for strain analysis. The analysis will be useful in the manufacture of steel products.

neering graduates do not have these assets so that individual ownership of a company is not possible, except in those few cases where the graduate inherits an ongoing business or plant.

The consulting engineering field is one of the few fields where the mechanical engineer can become an owner of a technical business. Strictly speaking, a consulting engineer can be a specialist in any field, such as vibration analysis, acoustics, or applied metallurgy. But the largest number of professional consultants are those engaged in two fields:

(1) *construction*—highways, buildings, bridges, and
(2) *mechanical equipment*—heating, air conditioning, ventilation, refrigeration, lighting, elevators, etc.

The mechanical engineer is especially well adapted to handle the problems of mechanical equipment, so that in every city of any size mechanical engineering consultants practice their profession of designing, specifying equipment, supervising installation, and checking the performance of equipment for office, factories, schools, churches, hospitals, and homes. This extremely large industry will, in the next 20 years, be involved in the almost complete rebuilding of the entire American city complex. Furthermore, from 30% to 60% of the total cost of a building is now composed of costs of mechanical equipment, such as water piping, drain lines, air conditioning, heating, ventilating, refrigeration, elevators, escalators, lighting, wiring, compressed air, vacuum lines, fire protection devices, etc.

The mechanical consultant works with the architect to make the building shell a livable and workable environment—whether the building is located in a hot, humid climate or in a cold and blustery environment. The office of the mechanical engineering consultant is a coordinating center where fans, pumps, compressors, vacuum pumps, lights, ducts, coils, pipes, valves, relays, switches, electrical controls, cables, conduits, and countless other components are designed to become a closely integrated structure. Most buildings are one of a kind. Just as each ocean liner is unique, so is each building.

The function of the consultant is to transform the needs of the client into mechanical equipment that will perform specific duties. The consultant must see to it that the equipment selected will handle the requirements; that the working drawings show clearly where the

equipment is to be located; that the written specifications indicate exactly what is desired; that the installation is made as planned; and, finally, that the installations are tested and found to be working satisfactorily.

Preparation for a career as a mechanical consultant requires experience that can be gained only through apprenticeship that follows a sound educational background in engineering. A mechanical engineering background enables the mechanical consultant to understand how a pump and its piping system work together; how the rating of a boiler can be interpreted for less-than-design-load conditions; or how the nature of solar heat affects the air conditioning load for the building. In addition, the consultants must deal with people. They must be able to work with architects who have equally demanding conditions to satisfy. They must be able to communicate with vendors and sales engineers who are anxious to have their products installed in the building. They may have to discuss alternate proposals with the client who is paying for the structure, and who is reluctant to spend money for a system that is unusual. And they must work together with city officials, building inspectors, church boards, school boards, hospital trustees, company directors, and other groups of clients and inspectors. Mechanical engineering consultants must be cost conscious, since they attempt to produce the best installation for the amount of money the client is willing to pay.

Other forms of consulting, usually of more specialized nature, are available in large cities. For example, an engineer with extensive experience in power plant design may set up an entire organization to supply a highly technical service to his or her clients, who may be utility power companies or other consulting firms. Then there are the specialized consulting firms, such as those which deal with sound, noise, and vibration problems. These firms have engineers who can analyze the acoustical characteristics of an auditorium, an office space, or a broadcasting studio. They can measure the wave length and intensity of sound in a space, prescribe treatment, and offer guidance to any client who needs their services.

New legislation requires a new breed of consultants. For example, federal regulations concerning worker health and safety have been

established by the Occupation Safety and Health Administration (OSHA). Some consultants will measure the sound intensity at various wave lengths at different locations before giving advice on making changes in the machines, enclosing them or treating the room surfaces with acoustical material. Other consultants are concerned with problems of excessive temperatures in the work area, the release of chemicals and dust particles, or the reduction of hazards from poisonous gases, explosive materials, or cancer-inducing chemicals.

Another specialized consulting engineering firm may deal mainly with ship design, lubrication problems, or management problems that include such diverse topics as personnel, plant design, and plant location.

Obviously, these consultants are engineers with extensive and intensive experience who have long records of research or development or inventive qualities to back up their reputation.

THE ENGINEERING TEACHER

A very small percentage of mechanical engineering graduates are siphoned off from the tops of college classes for future careers as engineering teachers. In contrast with days past, the engineering teacher is not limited to classroom teaching on a nine-month basis, but is heavily involved in research, consulting work, and summer employment in industry.

The usual requirement for engineering faculty at the college level is that the candidate possess a Doctor of Philosophy (Ph.D.) degree or the equivalent Doctor of Science (Sc.D.) degree, or be a specialist in some area of research, and have the knack of communicating his or her ideas orally and in written form to students. The usual requirement for faculty membership in junior colleges which offer pre-engineering courses is a Master of Science (M.S.) degree in engineering, science, or mathematics.

The salary scale of engineering faculty members in the larger schools is competitive with that of industry, and the main advantage faculty members possess over their industrial counterpart is that

their area of research is mainly based on personal interest.

Emphasis on research is heavy in most of the larger engineering colleges, since only by keeping up with fast-moving developments is a faculty member able to stay abreast with the times. With some exceptions, the research problems that faculty members attempt to tackle are basic in nature. For example, in the field of high-speed flow of gases (referred to as gas dynamics) the research is often centered on the manner in which the gas flows around an obstruction in the path of the flow. The results obtained from such research could be applied later to rockets or high-speed aircraft, but the fundamental research need not be immediately concerned with any specific application.

The choices of faculty researchers are their own. As a young faculty member one may choose to join an established team of research workers who are engaged in a large-scale problem that requires many brains and many hands. Or if such on-going projects are not available, an individual may decide to strike out on his or her own with whatever facilities the university is able to provide. In this connection, the National Science Foundation has given financial support to many young faculty members in the form of Research Initiation Grants.

The pressure on young faculty members to become productive contributors to engineering progress is as heavy as the pressure to produce on their counterparts in industry. To a great extent, young faculty members must be self-starters and be able to develop their own ideas. This is not a profession for an introvert, because it requires people who are interested in working with other people and guiding their professional development.

If a person has been too long in an industrial position, especially in a position where research or development is not involved, he or she may find it difficult to secure a faculty position. Contrary to the idea some people have that they would like to "retire" to a college community after 20 years of industrial practice, few college administrators will find such credentials attractive enough to warrant an interview. In other words, if an engineering teacher position is the ultimate aim of a young student, the commitment must be made within a few years after a doctoral degree has been earned. Fortu-

nately, most doctoral candidates have had an opportunity to do some amount of college teaching as part of their preparation for the Master's and Doctor's degrees.

Most graduate students are supported financially by means of:

a) fellowships, which provide financial support without any required teaching or research obligation,
b) research assistantships, which provide financial support with the requirement that the student engage in some form of research, usually sponsored by industry, government, or university, and
c) teaching assistantships, which provide financial support with the requirement that the student assist in some teaching function—which can include paper grading, laboratory assisting, quiz instructing, or even lecturing.

Ideally, doctoral candidates gain some amount of teaching experience during their study period, so that they, along with the faculty, can determine whether or not they have engineering teacher potential. The modern engineering teacher keeps abreast of developments by spending summers either in research or in industry as a temporary consultant who is given a specific short-term problem to solve. For example, mechanical engineering teachers have been invited to work in government research laboratories at Argonne National Laboratory, Oak Ridge, or at the Columbia River Laboratory, in which the many complex problems of nuclear power engineering are being worked upon. Some faculty members have worked during summers at aerospace laboratories operated by the National Aeronautics and Space Administration at a number of locations; some of the projects dealt with problems of the distant future and many involved the most advanced phases of physical science and mathematics.

Many faculty members have worked in industrial laboratories or in production plants, and have been assigned short-term problems that require immediate answers as well as long-term problems for future planning. The American Society of Engineering Education recognizes a young faculty member's need to be exposed to the industrial scene, and it has received a grant from the Ford Foundation to promote "industrial internships," wherein a young faculty member is paid to work in industry for a 12-month period on leave

from his or her faculty position. Such companies as Du Pont de Nemours have been regular industrial participants in this plan, in which a faculty member is assigned to a position where he or she can obtain an insight into the economic and engineering decision-making that takes place in industry. Several electrical utility companies have summer programs in which faculty members work on specific assignments or serve as supervisors of students who are employed for the summer at the end of their junior year in college.

One faculty member decided to expose himself to a different aerospace company each summer. At the end of six such summers, he was as well informed about aerospace industrial practice as any full-time employee of the industry. Another faculty member worked in consecutive summers with the Babcock and Wilcox Company (who produce large power plant boilers), General Electric Company (which produces, among other things, large steam turbines), and the Illinois Power Company (an electrical generating and distributing firm). During this period, he saw three different facets of the power generating field and returned to the campus with an overview of the industry that few possess. The kind of summer experience this faculty member gained can be brought back to the classroom and described as examples of the types of problems industry and the research laboratories are trying to solve.

Members of the faculty are commonly permitted sabbatical leave for a semester or academic year after six years of service if a worthy project can be submitted by the faculty member which will be approved by the administration. Typically, these leaves have been for research experience at laboratories or surveys of ongoing research at a number of laboratories. A variation of this off-campus experience is the ASME Senate Intern Program in which a faculty member becomes a technical consultant for a congressman. In most sabbatical leave programs, the faculty member is expected to return to campus and serve for at leas' one year.

THE RESEARCH AND DEVELOPMENT ENGINEER

The term "R and D" is commonly used in industry as an abbrevia-

tion for "research and development." The line between "research" and "development" is not a sharp one because an engineer may be doing research part of the time and development the remainder, depending upon the company and the industry involved. In fact, with a small company, the engineer may be involved in some design, some development, some testing, some research, and even some production on some product for which he or she is partly responsible.

Normally, development work involves an improvement of a product (such as an outboard motor), either in performance, appearance, or production. For example, an engineer could be working in the laboratory trying a new throttle control, planning a more compact unit, or utilizing a die casting to replace a part that had been machined previously. In the latter case, the engineer could be asked to find out how much the existing machined parts cost in quantities of, say, 1,000 pieces—and then to find out what it would cost to have the same parts produced in an assembled form, in a machine that produces the parts in a metal mold. If the parts are made within the plant or purchased from a factory specializing in die casting, the engineer might have to determine the cost. The unit cost might depend upon whether the order is for 1,000, 10,000, or 100,000 pieces. The cost analysis might depend upon whether the work is done internally within the plant or is farmed out to an outside supplier. Based upon this cost analysis, the decision may be made to change the method of manufacturing. In some cases, this might mean that fewer machinists are required or that some old machines can be retired or replaced with new machines. Since large numbers of the same model may be manufactured, each cent of reduction in manufacturing cost can mean large annual savings in the manufacturing process.

In some cases, a relatively simple change that does not decrease quality can save as much money for the company in one year as the salary paid to the engineer who made the recommendation. It is little wonder, therefore, that good engineers, with the ability to see a better way of doing something, are in constant demand. The "idea" person does not necessarily have to be handy with tools or be an expert draftsman or a good mathematician, but he or she does need the ability to devise, plan, and communicate ideas to some craftsman

who can make the desired changes.

In the final analysis, whenever a better machine or an improved process is devised for equal or less cost, the company is placed in a stronger competitive position which can result in the capture of a larger proportion of the total market. To the extent that the company prospers, the workers, management, stockholders, and the community also prosper.

Development is not limited to things or "hardware" (an industrial term for solid parts). It can also be in "software." This term refers to a design process that is handled through a computer. A rotating shaft, for example, will, under some conditions and at particular speeds, begin to vibrate strongly. Enough is known about the phenomena to calculate the frequencies which result in vibration; the calculation can be made shorter if the details are performed with the aid of a computer. In such a case, the engineer feeds the proper data into the computer and obtains valuable information for the design. He or she could have obtained the same data with the aid of a slide rule or calculating machines, but with a suitable computer program the process is reduced to a fraction of the time required by older methods. This assumes, of course, that the engineer has prepared a program, or has obtained one that will perform the desired steps in the calculation process. Based on the information which the engineer receives from the computer, he or she may decide to change the operating speed, modify the bearing distances, or make a change in shaft dimensions or material—again with the aid of a computer and program which will provide answers on the new critical speeds.

DEVELOPMENT THAT INVOLVES TESTING

Development can also involve testing. For example, mechanical engineers working in a research laboratory connected with a large oil company may be interested in the shape and size of the combustion chamber of an internal combustion engine. The manner in which the air-fuel mixture from the carburetor is introduced into the small space above the piston and then flows past the spark plug may affect the "knock" characteristics of the engine. Engineers have

proven through theoretical analysis that higher efficiencies require higher compression ratios (which means that the air-fuel mixture is pumped to higher pressures before igniting the mixture); and that this in turn requires higher octane fuel (that has less tendency to knock). Laboratory observations made with high-speed photographs taken of the flame show that if the fuel can be ignited by the spark plug so that the flame burns (without an explosion) then knock can be avoided. The presence of knock seriously reduces the power available from the engine and is damaging to the valves and piston.

In this development study, engineers may try building a different combustion head or a different arrangement of the spark plug, and then run actual tests on an engine that is mounted on a platform located in an engine test cell. The noisy engine is usually positioned in a specially designed room fitted with large double-glass windows through which the engineers can make observations. They are able to control the fuel and air supply to the engine, while a large number of instruments located at strategic points provide them with a tremendously large amount of data. They may use high-speed electronic instruments that will show the widely fluctuating pressures inside of the cylinder; they may have special temperature measuring instruments, called thermocouples, installed inside of the engine; they may utilize high-speed photographic equipment that will take pictures through a quartz window located on the side or top of the engine. Engineers may try a succession of models, hoping that the search is zeroing in on target, which is the best combustion chamber for the conditions of the test. If the fuel is changed to an unleaded fuel, they will probably include tests with the new gasoline. The testing may include an analysis of the exhaust gases, as well as a critical inspection of the valves, piston, piston rings, and cylinder walls for signs of undue wear, corrosion, or oxidation.

OTHER DEVELOPMENT PROBLEMS

Other examples of development, taken at random from company literature, show mechanical engineers working on the following problems:

1) One group may seek a better, more durable washing machine that uses less water than a competing model. The development work may include a better transmission between the rotating shaft of the motor and the oscillatory motion of the washer tub during the washing cycle. The development may consist of better flow of water through the clothes being agitated, and this in turn may consist of a study of the speed and turbulence of the blades on the rotating shaft.
2) Another group, in a consulting engineer's office, may be developing a computer program to remove some of the drudgery and errors from the necessary calculations of heat loss and heat gain from a building which is to be heated in winter and cooled in summer. The program will include information on the amount of heat energy the building will receive through the windows on each of the four sides, as well as the heat energy that passes through each of the four walls and the roof. Since the position of the sun changes with each hour of the day, as well as the day of the year, the calculations are tedious enough for just one hour of one day in the year, and intolerably tedious if other days and other hours are to be considered.
3) In still another project, an automatic lathe is being developed. It will operate from prepunched tapes that feed signals to the controlling mechanism of a lathe which will perform complex cutting operations. In other words, a tape can be developed that will automatically adjust the speed of rotation of the lathe, arrange for a given depth of cut, and then start the cutting at a given point and retract the tool at another predetermined point. Human operators may be assigned to oversee several lathes (or milling machines, shapers, drills, or grinders) and thereby reduce the manpower requirement.
4) Engineers are developing a deep-sea submarine that can carry out explorations of the sea at great depths and even bring up geological samples. Many experts predict that geological wealth at the bottom of the sea, which covers two-thirds of the globe, is untapped and of enormous extent.
5) A heart-lung machine is being developed for use during surgery. The patient's heart and lungs are by-passed so that the

surgeon has a dry and clear field to work in while performing the needed repairs. The machine takes over the pumping of the patient's blood to the rest of the body. As the blood comes out of the spiral section, it has the air removed from it and oxygen added to it before it is returned to the patient's arteries. Developments of this nature call for the close cooperation of physicians, engineers, and technicians.

6) Earth-moving machinery is being developed that will haul as much as 100 tons of earth or ore in a huge transport machine. The size of the machine can be visualized when the load of 100 tons is seen as sufficient to fill a large railroad car. A single tire on these monster vehicles is higher than the average door in a house and costs more than an expensive automobile. The giant machines can be operated by one driver who has power-assisted steering, braking, and dumping at his or her finger-tips. One of the development problems is to determine how the parts of the machine are to be shipped on highways or rail in order to be assembled at the site of digging.
7) Larger and larger oil cargo vessels are being developed for moving oil from the Near East without going through the Suez Canal. Ships that dwarf the imagination, with capacities over 300,000 tons, now ply the seas and feed an oil-hungry world. One interesting development, was the use of a special ice-breaking oil carrier to transport oil through the Northwest Passage from the northern slopes of Alaska to the East Coast of the United States. The experiment proved a success and the ship crunched its way through polar ice without being ice bound, but economic considerations have indicated that pipeline transportation of oil from Alaska is more practical.
8) Developments in shipment go beyond the transport of oil. For example, liquefied natural gas at subzero temperatures is being hauled in specially developed refrigerator ships from gas fields off the coast of Africa to northern European ports. Fresh fruit is transported in refrigerator ships to northern cities—bananas, for example, are handled in carefully controlled holds to prevent the fruit from ripening too fast and to reach the dinner table with just the right unscarred yellowish color that consum-

ers prefer. Grain ships have been developed in which the grain is pumped into the holds and sucked out of the holds by a pipeline.

There seems to be no end to mechanical development. Every issue of *Mechanical Engineering* magazine lists new developments, better methods of producing things, and improved mechanical products. The meager list given here does not begin to include the products and complex devices that are being developed by mechanical engineers.

THE DESIGN ENGINEER

Mechanical engineers, who serve as design engineers create a mechanical device that will perform a specific function. Their first product may be on paper, in the form of drawings and specifications, but the ultimate product is usually a piece of hardware. This can be small, a component of a large machine assembly, or it can be enormous and composed of thousands of parts all assembled into one large product. The mechanical engineer may be a designer of a component, such as a spring, and work alone on a project that is assigned to him. Or he or she may be part of a large team of designers working on one portion of a product that has to be carefully integrated with other portions of the same machine.

In large companies, some designers have become specialists. These specialists concentrate on some particular field and know more about the subject than anybody else in the organization. For example, designers whose specialty is gears and gear transmissions may be called upon by other designers whenever power transmission by means of gears is being considered for a product. They have at their fingertips a vast wealth of knowledge on types of gears, materials used for gears, availability of supply, stress limits, lubrication difficulties, temperature limitations, as well as a complete file of information on gears. In this highly technical world, in which information is pouring out at an unbelievable rate, even gear experts find that they must spend hours every month keeping up with the literature in their specialty field. Other engineers may specialize in fluid

transmissions, or spring design, or lubrication. Each industry and each period brings forth a new specialty area, and designers with experience and alertness soon find that their intensive knowledge is invaluable to the organization.

PRODUCTS THAT MECHANICAL ENGINEERS DESIGN

A survey of industrial literature shows some of the products designed by one or more mechanical engineers in conjunction with a large supporting staff of draftsmen, mechanics, and technicians.

1) The design team that conceived the huge machine that moved the 30-story rocket that blasted from the earth were thinking in big terms. The sheer weight of the machine and its load imposed pressures on the pavement so great that the support area had to be broadened to prevent collapse of the supporting earth. The moving tractor was larger than any built before that time. The engine, the power train, and the steering mechanism had to produce the desired result—namely, moving an unwieldy vertical object of immense value from storehouse to launching pad without jerkiness and with complete safety. The mechanical design of the support tower also included many interesting features of great complexity.
2) Snowmobile tractors have taken the northwoods country by storm. These agile devices are mechanical vehicles specially adapted to terrain covered with snow and ice. The engine, the power train, the lubrication, and the control mechanism pose interesting design problems.
3) The large radar antennae that scan the horizon for moving aircraft and other objects are large and bulky frames that either revolve continuously or move up and down to cover the sky. The mechanism for driving these large frames involves power transmission of precision origin, so that the observers inside the building know exactly the portion of the sky being scanned at any particular moment.
4) Even a relatively simple device like an automatic home washing machine requires design that arranges for a sequential

occurrence of events; namely, a required time period for washing, rinsing, agitating, spinning, and permitting the fresh water to enter and the used water to be ejected from the tub. This calls for timing mechanisms and relays to close the switch to the pump motor, or open the switch to the tub motor, or close the valve to hot water in some predetermined manner. Furthermore, the designer must arrange to have the machinery come to a stop if the tub becomes unbalanced and excessive vibration occurs. He or she must also provide for a safety mechanism that will automatically stop the fast spinning action of the tub when the cover is opened.

5) A paper-making machine appears to be as long as a city block. It includes a dense liquid entering the machine at one end that exits as finished paper at the other end. The design of one of these extremely complex systems involves motor drives, rotating cylinders (some of which are heated), knives that slit the paper, screens that permit water to be squeezed through, felt conveyors that carry the thin paper when wet, and rotating cylinders that serve as presses. The investment in each machine is extremely large, so that usually the machines are specially designed to suit the pulp supplied to the mill.
6) Complicated bottle-filling machines that pour powders or liquids into bottles, seal them, apply labels, and package them at speeds faster than the eye can follow involve an unusual assortment of mechanisms. Modern machines will even reject bottles or cans that are not completely filled, either by checking the weight of each can as it passes an inspection point, or by an optical scanner that checks the level of the liquid in the glass container. In some large food-processing plants, sheet steel or aluminum is delivered to the plant where can-making machines are located. Finished cans are fed into the filling lines and the packed containers roll out of the end of the line and are sent directly to trucks or to warehouses. The design of a can-making machine is so complex that only a few manufacturers are specialists in this field.
7) The design of a new model automobile is not a one-person process. The exterior contour of the car is governed by the

industrial designer with an art background. The design of the engine, transmission, clutch, brakes, and wheels are handled by specialist engineer designers who work within narrowly defined limits of space, performance, cost, accessibility, and repairability. Dozens of specialist designers who know their small field are each given their task. The function of the chief engineer is to see that the components will fit together and work together. The importance of each detail part can be understood when it is realized that a single mistake will be multiplied by the tens of thousands, and the recall by the factory of a defective design can amount to losses of hundreds of thousands of dollars and possible danger to the users.

8) A printing press that handles multicolored presses for magazines or books is just as complicated as the paper-making machinery described earlier. In this case, one color at a time is applied to the paper, and the paper must be so closely controlled in width and speed that the next color is registered precisely over the first color, or a blurry smear results. Then the paper must be trimmed, folded, assembled, and stapled—so that the end product accumulates at the end of the press. In order to control speeds, widths, printing, and drying at high speeds, adjusting mechanisms are provided for the pressman.
9) A chemical plant that processes crude oil and obtains gasoline, kerosene, fuel oil, and a host of other products at the end of the line is a maze of piping, tanks, heaters, heat exchangers, pumps, valves, and other devices. Here chemical engineers are employed for design, just as many mechanical engineers are involved in the design work. Whenever a new product is to be manufactured, companies frequently build a pilot plant that has a relatively small production capacity. In this plant the initial design is tested (the pilot plant itself can cost hundreds of thousands of dollars) and any deficiencies in the design can be corrected before the design of the full-scale model is begun.
10) At the Los Angeles airport, one of the airlines assists people by transporting them on a moving sidewalk. Basically, this is a conveyor belt with many safety features incorporated in the

design so that it will not be hazardous to those using it. The designer must be aware of materials which will resist wear, transmissions which will provide a smooth ride, and accessibility for repairs. The common escalator is an example of a moving stairway that presents design features like those of the moving sidewalk.

11) Located in the strip-mine areas of Illinois are ten-story, high-power shovels that remove the dirt overlay in an open-pit coal mine. The same kind of large shovels are located in the iron mines of the Mesabi range in Minnesota. These power shovels, with large scoops that can take huge bites out of the earth, are manipulated by an operator who handles the control console as expertly as an organist playing a pipe organ. The mechanism that permits full control of the bucket as well as the movement of the cab is a masterpiece of design.
12) The development of machines that mine underground coal by remote control has increased productivity in this dangerous work. The machines claw away at the mine face, and load the coal and rock on a conveyor belt to a coal car. The digging machines are able to get into narrow coal seams where there is no space for a pick miner to stand up.
13) Another transportation method under development is the transport of coal through a pipeline. The fine coal is mixed with water and the solid-liquid slurry is conveyed from mine mouth to a power plant many miles away. The method is in competition with rail cars and river barges. The legal problems of land acquisition for the pipeline can be as difficult to solve as the technical problems of pump design, wear resistance of the pipeline, conservation of water, and disposal of water at the end of the line.
14) The air-operated dental drill in the dentist's office is a precision instrument designed for ready manipulation in close quarters.
15) Crop-picking machines of all kinds are being designed and developed by mechanical engineers in cooperation with agricultural engineers. Each vegetable or fruit has some special qualities that must be considered in the design of the

machine. For example, in the Hawaiian pineapple fields, the gathering machine is basically a conveyor belt upon which the human cutters load the freshly cut fruit. The conveyor belt sticks out over a large number of rows so that a crew of cutters follows behind the belt. The fruit is moved by the belt and buckets and finally is deposited in the truck that moves the fruit to the cannery.

In re-examining the preceding examples (and this is only the beginning of an endless list), there seems to be no common denominator. Certainly, no mechanical engineering course is devoted to the "design of a tire-making machine," or the "design of mechanical toys." And yet there does exist one common denominator in all of these examples—the *motion of mechanical parts.* In the courses that the mechanical engineering graduate has taken are such subjects as:

statics—forces considered apart from motion,
dynamics—parts that move,
vibrations—that result in oscillations and fluctuations of parts,
stress analysis—what forces materials can withstand,
fatigue of metals—learning which metals become tired and break after repeated application of stress,
metallurgy—study of metals and their constituents, and the manner in which deformation takes place,
heat treatment—for learning about the metals that become stronger or evidence different properties after treatment with heat,
metal cutting—for determining what forces it takes to tear metals apart by cutting action,
metal fabrication—for determining how metals can be cast, punched, drawn, molded, and welded,
kinematics—for relating mechanical parts that move with respect to each other,
transmissions—study of gears, shafts, belts, chains, hydraulic devices, magnetic devices, and clutches,

creativity—synthesizing to create a new machine,
computers—to provide a tool for solving complex equations rapidly.

Basically, mechanical engineering students are not taught how to design a "shoe-making machine" or a "monorail transport vehicle." But they do acquire a background that should enable them to approach a problem by deciding what the machine is supposed to do. At that stage, the engineers must (a) devise several possible methods of accomplishing the given job, (b) make whatever calculations or preliminary designs are necessary to enable them to concentrate on one or two likely alternatives, (c) obtain some idea of how the machine might be built, at what cost, and during what time period, and (d) finally converge on a final choice.

THE DESIGNER'S PROCEDURES

Designers are creators, inventors, innovators, and practical people. They may accomplish their work with any or all of the following procedures:

1) They may make sketches on a sheet of paper showing how the rotary motion of a motor shaft is changed to an oscillating motion.
2) They may stop to calculate such necessary items as: how fast the motor should run; how big the motor is; what the critical speed of the shafting is; whether the parts will be at unusual temperature or be in a corrosive environment—and if so, what materials should be specified.
3) They may carry sketches to an experienced mechanic and discuss the manufacture of the parts; what machine to use, with what tolerance (how accurately the part must be made); and how rapidly it must be manufactured. Designers should have enough background in manufacturing processes so that they can communicate effectively with a master mechanic, and at the same time they must have an appreciation for a product that will sell.
4) Designers may carry problems to the purchasing agent to find

out sources of supply of motors, steel, bearings, casings, and other purchased parts.

5) They may confer with the sales engineer, who brought in the idea of the device from the field, to determine what the prospective customers are seeking. What is the competition? How many could be sold and at what price? What number of parts must be made before the development costs are earned?
6) They may ask the model shop to make a first approximation, based on sketches, to see if the device will work as planned, if it can be assembled and in what sequence, if the device can be disassembled when repairs are needed, if the parts function together properly, and if the device might be simplified.
7) They may discuss the preliminary design with patent attorneys to determine whether a patent search should be initiated, or a patent applied for from the U.S. Patent Office. In most companies, the inventor assigns the invention to the company, and the company assumes the tedious and costly process of conducting a search and preparing the application. An understanding is usually specified in the employment contract as to the method of compensating the inventor in case any royalties are received.
8) Designers may ask the testing laboratory of the company to obtain any competitive models and to measure their performance against their design.
9) They may ask the industrial designer for the firm for ideas on the casting, or housing, for the product to make it more attractive, safer, lighter, or more durable.

A good designer is usually not fresh out of college, but is an experienced engineer who knows where to go for information not contained in books or handbooks. The experienced designer knows who to call for advice on new materials, costs, and availability. He or she should possess an unusual talent for creativity. No college course can teach "creativity" if the student does not possess the spark. Colleges can, however, teach those procedures which enable students to assemble facts, consider alternatives, and stretch their creative abilities to the utmost.

THE PRODUCTION ENGINEER

Mechanical engineers engaged in production make the wheels of industry turn around. They deliver the goods. They are the backbone of productivity. The individuals engaged in production deal with things, but they must also be involved with people. They are usually considered to be part of the "management team," but the people they deal with every day may be technicians, skilled craftsmen, machine operators, assembly line workers, and others who know more about their particular jobs than anyone else in the shop.

Production engineers do not need to know as much about a particular machine as do the specialists who operate it, but they should know enough about the process and its production capabilities to make a decision in case the machine should have to be shut down for repairs. Were enough parts produced by the machine kept in storage to keep the main production line going? Can the work be shifted to another machine? The life of a production engineer can be exceedingly pleasant when the machines are humming and the quality of production is maintained within desired standards.

But life can be hectic when part of the production machinery breaks down, or when the incoming raw products differ from the usual run, or when labor shortages occur, or when a "rush, rush, rush" order takes priority over the normal production run. Alert production engineers anticipate trouble. They adopt preventive maintenance techniques (in which parts are replaced before they break down). They try to break the bottlenecks that hold up production (by using more machines at some spot, more experienced workers at a key spot or re-aligning the machines for better flow of materials). They become aware of personal problems that may be affecting the performance of an operator. They are aware of possible safety hazards (such as wet floors, unsteady piles of crates, improper attire worn by machine operators, noxious fumes from a cleaning operation, poor visibility from dust-laden light fixtures, exits that are blocked with stored merchandise, and unsanitary washrooms).

Production engineers interpret policies of top management to the shop workers, and must be able to communicate the ideas in language that is clear, plain, and simple. At the same time, they must

be able to talk with top management in the terms that management best understands—those of production units, delivery dates, and dollar costs. One of the basic requirements for a good production engineer is that he or she must be an "applied psychologist," able to deal with all kinds of people.

The requirements for success as a production engineer are not the same as those for a research engineer. Brilliance in mathematical analysis is not necessary—but a keen understanding of human nature *is*. Research engineers place great emphasis on logic and order and consistency. Production engineers must be able to make decisions rapidly, and frequently on the basis of experience and intuition. They must also improvise alternate methods or procedures in case a mainstream machine breaks down, and be able to command others in times of production crises.

Something new has entered the production scene—industrial robots. These specialized machines are used under conditions where people could not work long. For example, if the temperature near a melting pot reached dangerous levels for a human, it would not bother a robot built with metal parts. Or, if a process results in an occasional spill of poisonous gases, a robot could continue working without a gas mask.

Some robots do replace humans. Many years ago an automobile frame plant produced frames with only a few humans operating the controls for a robot-like machine. The machine was needed when large quantities of the same product were being made. A spectacular example of a robot was the digging machine that landed on Mars to dig soil samples and to test for biological materials. The engineering operators at the controls were millions of miles away. Robots have been built for handling fuel rods in a nuclear plant. Basically, robots are extensions of human arms, legs, and brains into areas where humans could not or prefer not to work.

College education in mechanical engineering does not specifically train students for production engineering jobs in a plywood factory, a fertilizer plant, a metal-casting foundry, a cement mill, a copper mine, or an electronics factory. However, they have had extensive courses in machine design and metal fabrication. They have also had many hours of engineering laboratory studies where they have had

to work with others on a project. They have had experience in applied logic—in arriving at conclusions based upon a given set of conditions. Basically, they like to solve problems, whether they involve people or machines, or both.

Some people have a knack of dealing with others that formal college courses alone do not teach. Some gain this ability by becoming officers and leaders of student technical and social societies. Others strengthen this ability by outside activities, such as participating in athletics, joining a debating society, becoming a salesman in the summer, or enrolling in the Reserve Officers Training Corps. In any case, the progress of these gifted persons up the industrial organization is frequently more rapid than those in any other phase of engineering work. Management people claim that they are constantly seeking "leaders," those who will accept responsibility, those who will make decisions, those who are flexible and willing to change, and those who can be trusted to perform during emergencies. Production engineers are not the only engineers with these characteristics, but the position demands the same types of people that management seeks.

THE DISTRIBUTION ENGINEER

One large segment of industry not recognized as a distinct field of endeavor by the layman is that referred to as the "distribution" phase. Manufactured products, whether they are bags of cement, packages of cereals, bottles of beer, or automobile accessory parts, are manufactured in one or more localities in the country or world. These products have to be stored in warehouses and distributed from them wherever and whenever a demand occurs.

This field of work falls within the province of the industrial engineer, but there is no clear-cut division of responsibilities, so that many mechanical engineers find successful careers in this huge distribution enterprise.

The distribution engineer, as broadly defined here, is involved with some of the following tasks:

1) *Packaging*—a box of cereal or bottle of vinegar must be filled,

sealed, labeled, and boxed. A bulky filing cabinet must be packaged in a cardboard container so as to avoid scratching the surface finish or denting the cabinet. The file drawers are protected so that they do not move around during shipment; handles are placed in a container and installed after the container is opened. Manufacturers make great efforts to provide for containers that will withstand some degree of abuse but which are not prohibitive in cost.

2) *Handling*—The container must withstand handling by fork-lift trucks, tongs, hand trucks, or hands—and be resistant to bumps, falls, and weather. Finished lumber is shipped from the West Coast lumber sawmills to the other sections of the country in tightly bound packages that can be handled by machinery instead of singly, by hand.

An unbelievable device for handling heavy objects has been developed that, at first glance, appears to be an antigravity device. Actually the machine is operated by air pressure. The principle of an air bearing is simple—compressed air is released below a flat surface and the air escapes outwards—in doing so, the heavy object is suspended in air. The application of a small, horizontal force will cause the object to be moved readily. An interesting example of the air bearing is the 1750-ton Aloha Stadium in Honolulu, which has a height equivalent to a 14-story building. The seats in the stadium can be rearranged to form four different configurations depending upon the event to be held on the field. The massive stands are lifted a fraction of an inch by air pressure alone and then moved with small tractors. Modifications of air bearings are used in Hovercraft ships and for moving heavy steel plates in a mill.

3) *Warehousing*—Goods and parts must be stored in strategic locations so that shipments can be made promptly by truck, rail, or air freight. The decision has to be made by management as to where the warehouses should be located in the world to best handle incoming orders, and how much of each item must be kept in stock at any time. Since some warehouses contain thousands of items, and each day sees items being received and shipped out, the keeping of a current inventory becomes a formidable task. Data processing for inventory control has

been introduced to make it possible to keep a daily record of what is in stock and what should be ordered.

4) *Transportation*—The number of trucks in the fleet, the number that are leased, the maintenance garage, the record keeping to keep track of what is being shipped to where, and the rapid loading of rail cars, all involve people who know their business and will keep the goods rolling.
5) *Layout*—If thousands of different items are kept on hand, should they be stored in bins, boxes, crates, or on the floor? How does one move material from the storage area to the shipping deck? What is the path for conveyors, trucks, hand cars, or even bicycles with baskets? How are the records kept when material is placed in storage and when material is removed? How are slightly different models of the same equipment separated in storage?

The requirement for a distribution engineer is for a person who enjoys the specific challenge of trying to maintain order in a situation that can easily lead to chaos. For example, every repair shop—whether for aircraft, automobiles, trucks, washing machines, radios, television sets, or lawn mowers—depends upon one or more distribution centers for repair parts for both new and old models. One of the wonders of American industry is that the repair parts get to the place where needed at a particular time. Consider the hundreds of models, sizes, and colors of a relatively simple device as a washing machine. When an impeller or a timing mechanism breaks down, and a call goes out for replacement, at some distant point a replacement is found, shipped, and hopefully received in reasonable time. The distribution engineer works at the supervisory job of being sure that each needed part arrives within a reasonable time.

The distribution engineer is not merely a supplier of repair parts, but the one in charge of distribution of new parts for a huge assembly plant. For example, steel warehouses are located at strategic cities throughout the world to handle the orders for rolls of sheet steel, reinforcing rods for concrete construction, I-beams for building and bridge construction, and heavy plates for shipbuilding. Dozens of different sizes and compositions of steel rods, bars, plates, channels, and beams are stored. Flat cars bring new supplies and remove

ordered goods, so that some distant factory is not kept waiting for a basic product.

To qualify as a distribution engineer, a person must be able to oversee a tremendous amount of detail without becoming panic-stricken; create a master plan that is not too unwieldy; and work with people in warehouses, rail terminals, and shipping centers. He or she must also be cost conscious. The requirement is not necessarily for an individual with mathematical expertness, but for one who enjoys mathematical precision. The task of maintaining inventories has been aided by data processing equipment, creating a greater need for people who can utilize such machines for intricate planning of the distribution process.

THE SALES ENGINEER

The work of the sales engineer is not confined to mechanical engineers; in fact, graduates of every branch of engineering can and do qualify for this type of endeavor. A sizable group of every graduating class of mechanical engineers does become involved in this segment of commerce.

Sales engineers for engineering firms do not stick their foot in the door of a homeowner and ask, "Would you be interested in a steam turbine today?" They are welcome representatives of engineering firms whose main customers are other engineers and consultants involved in design. For example, a sales engineer with a company that manufactures large steam turbines, as big as a house, will be asked to discuss the needs of a large electric power-producing company in six to ten years. In the past, electrical power needs doubled about every ten years. Recently, because of energy conservation measures and an economic recession, the growth rate decreased for two years. However, all signs point to a renewed increase in electrical demand as production increases and the population becomes larger. It is true that power networks exist so that electrical power can be transmitted from one state to another over interconnecting power lines, but every utility company attempts to stay abreast of its local power needs, and to rely on its neighbors only in emergencies.

Hence, the utility company and its design engineers maintain relationships with companies that produce boilers, steam turbines, steam condensers, pumps, electric generators, transformers, and fuel-handling equipment. The utility company engineer will have target values for the next plant, and will state the megawatt capacity and the possible plant location.

The sales engineer for the turbine company must be able to discuss a host of highly technical details of the following type: Is the company considering a nuclear plant? If so, which type? What delivery dates are being considered for several years ahead? If a fossil fuel is being considered, will it be oil, or coal? If coal, is a power plant near the mine being considered? How will the coal be shipped from the mine to the power station? By a conveyor belt, a special shuttle train, river barge, or even a pipeline that carries coal and water? What will be the source of cooling water for the steam condensers? Will the enormous requirement for water preclude the use of river water or lake water, because of possible overheating of the water (thermal pollution)? Can a man-made cooling pond or lake be built? Is a cooling tower feasible for cooling the condenser water? What will be the steam pressure? How much superheat of steam is contemplated? What voltage of electricity and what phase is to be generated? What linkages with other utility lines are being contemplated? What consulting firm will handle the design? What are the delivery dates for the various required units?

These questions and criteria could go on for hours, since millions of dollars and thousands of hours of labor are at stake. This information is relayed by the sales engineer to the engineering design group of the firm so that they, in turn, can make preliminary plans. Sales engineers do not have a firm contract in their hands at this point; all of their inquiries and numerous visits may end up with the contract in the hands of a competitor. The liaison between the utility company and the manufacturer is maintained by them. They *are* the firm, as far as the utility company engineers are concerned.

Conversations of this nature cannot be carried on by people who are not familiar with engineering in the finest details. The well-trained sales engineer will usually have had a period of factory training in the shops, on the drawing board, in the testing laboratory, and

finally as an apprentice with an experienced sales engineer. The prosperity of the workers in the plant—indeed, the very existence of the company—may depend upon the expertness of the sales engineer and the service rendered by him, since without sales most companies cannot exist.

Sales engineers will usually be required to do some amount of traveling, depending upon the product and the territory that they cover. Sales engineers can have their clients (such as consulting engineers) clustered together in one engineering center in one large city, so that their sales territory might be only one building and they may seldom be away from home. Another sales engineer may cover half the continent and spend considerable time traveling. Still another engineer could have an international clientele and carry sales portfolios all over the world.

In addition to an engineering background in thermodynamics, combustion, fluid mechanics, and heat transfer, the sales engineer must be able to meet people, to communicate verbally and in writing, and to represent his or her company. A large industrial firm is often considered as an impersonal enterprise without a soul or a personality. To many clients, the sales engineer is "the company." If he or she renders good service, the company is considered to offer good service. If he or she gives a negative impression of quality of merchandise and service that the company can offer, the company is branded as an inferior outfit.

Is it little wonder, therefore, that companies are extremely selective in choosing their representatives? The demand for neat, pleasant, courteous, competent, and trustworthy engineers is for good reason.

Competence in intricate mathematical computations or ability in design are not necessary for sales engineers, but expertness in human relations rates very high indeed. The ability to speak convincingly and to express ideas in writing are essentials for the sales engineer. This, of course, includes the knack of listening and gleaning the essentials from a conversation. The chances for advancement in this activity are as great as in any of the other engineering activities, especially since the sales engineer may be exposed to many top management people in his daily work.

MANUFACTURER'S REPRESENTATIVE

A few engineers with a leaning towards technical sales have become manufacturers' representatives—many as independent business people and their own boss. Such representatives may handle products of more than one small or medium-sized company. For example, in the building products area, a representative may be the exclusive agent for a number of different items such as air filters, air washers, fans, pumps, controls, valves, pipes, and dozens of other items used for buildings or in a manufacturing process. Knowledge of function, performance, and quality of the items enables the representative to assist a client in buying a product that will do the job at an acceptable cost.

MECHANICAL ENGINEERS IN LAW CAREERS

Large firms seek patent lawyers who can determine the uniqueness of an idea, a design, or a method that has been developed within the firm. In most companies, an employee-inventor assigns patent rights to the company on ideas generated while he is employed by that company. The company, in turn, will determine, through its patent lawyers, whether the idea is patentable and whether the company should go to the expense of proceeding with the patent application. This is a costly procedure, but many companies prefer to apply for a patent if only to prevent some other company from enjoining them from using a similar idea at a later date. Most patents are not valuable in terms of dollars, but they may be of value to the company as bargaining material for other patent rights held by another company. Most companies do have a protective clause in their contract whereby the employee-inventor will be able to share in any profits that might accrue.

The patent lawyer is, therefore, the watch dog for the company in its dealing with other companies. If a patent infringement seems to be involved, the patent lawyers will prepare a case that will stand up in the courts. In many companies, patent lawyers are asked to serve as "hound dogs" to "sniff out" patent applications that seem to have

merit. Perhaps the company is interested in contacting the inventor or another company about a license agreement to use the invention. Obviously, the patent lawyer must know both law and engineering. A patent lawyer who is expert in electronic circuits or chemical synthesis may become a specialist in his or her field.

The basic requirement for a successful patent lawyer is the determination to complete two distinct careers and meld them together. Good patent lawyers must be discerning enough to pick out the unusual feature contained in a patent application. They must possess a good memory of features contained in applications that they have reviewed in the past. They must have the ability to wade through wordy descriptions rapidly and to dig out essential features. They must be able to express themselves verbally as well as in writing, since words are the main medium of communication.

Some few mechanical engineering graduates have taken another path following law training and have sought careers as corporation lawyers. In such cases, formal training in engineering does not play as large a part as with patent lawyers—except that the discipline of engineering study and the training received in problem-solving proves to be as useful in law as in engineering. The few who have entered this top management field find that the problems with which they deal are primarily financial ones. They also frequently involve national politics and international trade. An engineering background may help those who become associated with companies dealing with highly technical matters or with scientific products.

ENGINEERS IN OPERATIONS RESEARCH FIELDS

Those mechanical engineering graduates who find a special interest in the areas of production, inventory, distribution, and sales have found an outlet other than the M.B.A. route towards higher managerial responsibilities. Some graduates of mechanical engineering seek more work in industrial engineering or industrial administration, since these rapidly expanding areas of engineering are especially well developed in industrial America. The industrial engineer has found that computer and data processing equipment have

opened up new areas of analysis that were not possible before. Emphasis formerly given to such subjects as time-and-motion study (standard time values), plant layout, safety, quality control of products, reliability, personnel management, wages and incentives, etc., has been overshadowed by a veritable explosion of interest in what is referred to as *operations research.* This area is one which emphasizes analysis of an operation to find the best solution among many alternatives. The problems of management are usually so complex that business judgment was frequently based upon experience, insight, or hunches. The field of *operations research* attempts to analyze a complex business or industrial operation in a systematic and logical manner so that all factors which might have an influence can be examined critically and a logical answer found. Reliable data are needed by the engineer, and any assumptions made must be reasonable. This approach is especially attractive to the engineering mind—which is trained to find the facts, organize them in some logical order, and then apply logic in analyzing the data.

Some engineering graduates are finding this path through industrial engineering towards managerial responsibilities more attractive than the M.B.A. approach, especially since a Master of Industrial Engineering can be attained in less than the two years required for the M.B.A. degree. An interesting trend in the M.B.A. educational program is the increasing attention given to operations research; in time, both the industrial engineering and M.B.A. programs may have a common ground in this new field.

WHAT ABOUT ENGINEERS IN GOVERNMENT?

First of all, let us distinguish between engineers in politics and those in nonelective type government service. If we consider the latter only, several graduates out of each large class will enter some form of government service, sometimes for a short period, and sometimes for a lifetime career. Some of the more common forms of government service include:

Military

As a direct result of obligations assumed by the students enrolled in the Reserve Officers Training Corps, they will serve as officers in one of the military services for a period of about two years, after which they can revert to civilian life if they so choose. Most of the military services provide for graduate study periods for career officers at civilian institutions.

Research Laboratories

A large number of highly regarded laboratories are maintained by various agencies of the federal government, many of which are seeking people with engineering backgrounds. The laboratories most commonly mentioned are those connected with the aerospace effort (NASA), the nuclear power effort (AEC), the National Bureau of Standards, the Bureau of Mines, the Geological Survey, and the many defense agencies—called *Operating Agencies.* The federal government, and to some extent the state and municipal governments, maintain operating agencies for power-generating stations, irrigation projects, lighting systems, highways and streets, and other service functions. For example, recruiters from the large-scale water-reclamation services in the western United States seek mechanical engineers who will work with civil and electrical engineers on the huge projects in which rivers are dammed, hydroelectric power is generated, recreational lakes are formed, and water is made available for irrigation farming as well as for industrial use.

Recently, recruiters have been coming from the large municipalities to find engineers who are willing to work on the almost overwhelming problems of the city—including transportation, lighting, streets, traffic control, waste disposal, building codes and inspection, water supply, underground electrical and gas supply, airport operation, sewage treatment, and zoning of the city. Many of these service areas are those for which civil engineers have been specially trained, but, in view of the large demand and the complexities of the problem, many engineers from the other disciplines have been attracted to this field. For example, a mechanical engineer became so

involved in a citizen group making a complete engineering survey of traffic, population, industry, and growth in a suburb of Minneapolis that he gave up his job as a development engineer in an industrial firm, moved into the position as highway director for the state, and later became a deputy director for the federal highway system. He had no specific college training in highways or traffic, but the problem-solving approach that had been developed during his research and development career was easily adapted to the requirements of his new interests.

WHAT ABOUT ENGINEERS IN POLITICS?

With a few notable exceptions, engineers have not entered into the arena of national or state politics. It is true, however, that many engineers have served without pay on local improvement boards, zoning boards, community planning groups, and park boards. Furthermore, the professional position of City Manager is most frequently occupied by engineers—especially civil engineers. By and large, however, the number of engineers in the elected posts of state legislature, federal legislature, and the executive branches of state and federal governments is exceedingly small.

Many leaders in the engineering profession consider this small political contribution a shortcoming of the past, and one which must be changed in the future. They feel that engineers should enter the rugged game of politics and become more directly involved in the social and economic problems of the city, state, and nation. Certainly, many of the legislative bills and measures over which Congress deliberates require the careful study of those familiar with engineering. Consider, for example, the technical contents of the legislation proposed to handle the nation's problems in such areas as:

antiballistic missiles
defense strategy
national highways
a national rail passenger system
communications satellites

supersonic transport
air safety and air traffic control
oil spillage from off-shore oil wells
location of nuclear power stations
reduction of air pollution
automobile safety laws
safety legislation in mines
noise reduction in factories and near airports
fuel and energy resources
strategic minerals
deposit of nuclear waste products
housing, codes, and enforcement
model city planning
future space exploration
technical manpower resources
oil pipelines and the ecology

William Miller, head of the Washington office of ASME, was quoted in *Product Engineering*, March 1975 as follows: "The new Congress has only three people with technical backgrounds: John Glenn, the astronaut, in the Senate and in the House; David Emery of Maine, an electrical engineer; and Gary Meyer of Pennsylvania, a mechanical engineer. Most Congressmen are a bit uneasy with technological discussions ("never show them an equation") and their staff members, especially on the House side, also usually come from legal to political backgrounds."

Then in 1977, Jimmy Carter assumed the position of President, the second engineer since the days of Herbert Hoover in the twentieth century. President Carter is a graduate of the Naval Academy, which is basically an engineering school, and received additional training in nuclear engineering.

The engineering profession has taken some positive steps towards providing technical assistance to legislators who need information. Many engineering societies have established Washington offices. In addition, Congressional Fellows have been appointed for one-year terms to provide technical input to some congressional committees. These Fellows are usually faculty members, but occasionally are

from industrial research engineering groups.

A few engineering graduates have participated quite successfully in such humanitarian operations as the Peace Corps and VISTA programs, judging from the demand for more of the same sort of volunteers. If the day comes when the engineering graduate is willing to face the problems introduced by the unpredictable human race, and to become deeply involved in the hectic world of politics, the world will be the richer for having problem-solving specialists attacking the most formidable problems that now face society. Whether or not more graduates will move towards this arena of social service and politics will depend to some extent on the influence of faculty and the attitudes of family and community towards these problems. In recognition of the larger part that engineering graduates can play in future society, the engineering curriculum includes many courses in social science and the humanities, so that the graduate is better prepared to cope with people and human needs.

WHAT DOES A MECHANICAL ENGINEER DO?

One is inclined to answer that mechanical engineers are so versatile that they can readily adapt themselves to any line of endeavor. We have observed that once students have completed their Bachelor of Science degrees they can find a niche for themselves, and become involved in the type of work that interests them. In the initial job, the graduates from the upper quarter of a class may have some advantages in better-paying offers with a larger number of concerns. However, as the years roll on, some of those, whose academic performances may not be as high, manage to find the type of job that permits them to make substantial contributions to their firms, and the rewards are often as good as those of engineers with a better start. Realistically, since a considerable amount of screening has already taken place before one graduates with an engineering degree, there seems to be a place for the brilliant as well as the average intellect; for the impatient person as well as for the plodder; for the introvert as well as the extrovert; for the charmer as well as the recluse.

A review of extensive alumni records of graduates reveals that

many graduates, for various personal reasons, have changed their profession after completing their engineering degree. They have become successful ministers and priests, accountants, physicians, and lawyers. Out of an engineering background have come band directors, YMCA secretaries, real estate brokers, investment bankers, football coaches, army officers, technical society secretaries, and every sort of entrepreneur one can name. A query directed towards these graduates indicates that the engineering background proved helpful to their eventual careers. For example, one minister of a church revealed that his engineering background was a big help to him during the building campaigns of his church.

No one will deny that the undergraduate's study period is demanding. The mental discipline required, the study habits acquired, the training that emphasizes the marshaling of facts, and the problem-solving techniques that the student learns help in later life far more than the mastery of some special subject matter. We believe that these are the qualities industry is seeking and willing to pay a high price for in this day when leadership material is so sorely needed. The engineering student body almost automatically excludes the lazy, the shiftless, and the unimaginative, unambitious person.

BOOKS AND PAMPHLETS

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National Society of Professional Engineers. "Engineering—A Career of Opportunity." NSPE, 2029 K St., N.W., Washington, D.C. 20006.

Pollack, P. *Careers and Opportunities in Engineering.* New York: E. P. Dutton & Co., 1959.

CHAPTER 3

PERSONAL REQUIREMENTS

A CHECKLIST FOR THE HIGH SCHOOL STUDENT

A tendency exists on the part of high school counselors, parents, and other interested laymen to form certain stereotyped images of what an engineer does and what is required of the prospective engineer. After watching hundreds of graduates of engineering colleges achieve satisfactory and successful careers in all sorts of occupations, we are most reluctant to say, "There are certain interests and characteristics you must have if you are to be a successful mechanical engineer." As one of our freshmen once wrote, "You do not have to be a walking brain spouting out facts and figures like a machine gun. You can be human and still be an engineer."

In order to put this discussion on a personal level—one that applies to you specifically—we have prepared a check list that includes most of the subjects covered in high school, as well as some "interest areas" of young men and women. We suggest that you consider the following statements carefully and make a check under the column which most closely identifies your evaluation of your interest. Below your response we explain why the question is of interest and the part that your reply might have in reaching a decision as to your future profession.

My interest in	Strong	Fair	Slight
mathematics is:	_____	_____	_____

In most engineering courses, mathematics is one of the basic tools to be used in analysis and design. Engineering colleges recommend, therefore, that high school students take as many courses in math-

ematics as they can include in their program. Basically, mathematics is like another language. It utilizes distinct symbols; it can convey ideas in compact and precise form; it is based on logic and sense. If your interest in math is only fair, you might be able to compensate by working harder at the subject, but if your interest is slight, then engineering will be a difficult area to master.

My interest in physics is:	Strong	Fair	Slight
	_____	_____	_____

Physics treats of basic subjects, such as atomic and molecular structure of matter, forces and reactions as in mechanics, heat and work, electricity and magnetism, electromagnetic spectrum and light, optics, sound, and vibrations, etc. For the student interested in mechanical engineering, topics in mechanics, heat, electricity, and sound will be more important later on than some of the others, although all can be shown to have some bearing on various aspects of engineering. For example, a knowledge of atomic structure is a necessity for a mechanical engineer interested in the field of electrical power generation. If you are interested in learning what makes things "tick," and how the fundamentals of physics can be applied to a machine or a device or a process, then your interest in physics will form the basis for a solid background in the fundamentals of physical science. On the other hand, if your interest in these subjects is only slight, the engineering path may prove extremely difficult.

My interest in chemistry is:	Strong	Fair	Slight
	_____	_____	_____

A strong interest in chemistry is helpful to a student who thinks that his or her future career might be in the areas of:

Combustion

Exhaust gases from internal-combustion engines used in automobiles and diesel trucks, and from gas turbines used in jet aircraft engines involve exceedingly complex chemical combinations that result from the burning of so-called hydrocarbon fuels, both with and without additives.

Metals

Steel is a complex mixture of iron, carbon, and a host of chemicals, some of which are in minute quantities. High-strength alloys include mixtures of nickel, tungsten, chromium, manganese, molybdenum, cobalt, and many other trace elements.

Chemicals

The expanding field of plastics is based on synthesis that originated in the chemical laboratories, but which is carried into practice in pilot plants and full-scale plants by engineers.

Quite realistically, many mechanical engineering students who have only a fair interest in chemistry have not been handicapped severely in later studies or in later careers.

My interest in English rhetoric is:	Strong	Fair	Slight
	_____	_____	_____

English is a communications skill. Without some competency in this form of expression the engineer is severely handicapped in the ultimate rise to the top. Many high school students have the mistaken notion that a lack of interest or proficiency in English is a sure sign of aptitude for engineering. This is not true. The following experiences in communication are common in engineering practice:

Verbal

A development team issues instructions, directions, recommendations, and conclusions to each member of the team through verbal orders that should be clear and precise.

Reports

Engineers are required to submit reports of tests, research find-

ings, and field analyses in concise, unmistakable language that can be understood by those requesting the report.

Presentations

The engineer is called upon to present a report and make a recommendation to some board or group; the chief engineer will describe the feasibility of producing a new machine; the section head may show how a given problem could be handled, depending upon time restrictions.

Instructions

When a new product is developed and produced, installation directions, assembly details, operating procedures, and repair instructions must be written so that people not familiar with the product can be informed.

Sales

At some time in his or her career, every engineer needs to sell an idea, a scheme, a method, a procedure, or a product.

Committees

All engineers will find themselves becoming involved in some committee activity, whether as a member of a safety committee for the shop, a product review committee for the plant, or a grievance committee for employees. They will be judged by their ability to listen and by the soundness of their ideas, many of which will be voiced extemporaneously.

Chairman

Many times in his or her engineering career an engineer will find it necessary to chair a meeting, to serve as toastmaster at a dinner, or to direct some activities of a technical society.

Correspondence

Business-letter writing becomes a requirement for all engineers. Either they write the draft of the letter in longhand, prepare the draft on the typewriter, or dictate the letter to a machine or to a secretary. In any case, their command of English must be adequate to accomplish the task quickly. Furthermore, they must have some appreciation of the manner in which words can affect people; some words, or combinations of words, can become "fighting words" that antagonize people rather than convey a message.

My interest in graphics is:	Strong	Fair	Slight
	_____	_____	_____

Not all high schools offer courses in graphics, but some do offer courses in mechanical drawing or graphics. The engineer, as well as the architect, employs a pencil or chalk as a major means of communicating ideas. Many ideas can be conveyed most readily to another person by means of a freehand sketch, a diagram of the various parts in the assembly, a perspective of the entire layout, an isometric drawing, or by plotting a curve. Practicing engineers will consider graphical representation as naturally as they do written prose or a mathematical equation, and will use the mode of expression best suited for the purpose at hand.

My interest in computers is:	Strong	Fair	Slight
	_____	_____	_____

Introductory courses in computers are now offered in some high schools. If they are not, such courses will be included in the freshman or sophomore courses in college. The engineer uses the computer as another tool, a replacement for the slide rule, and will utilize it whenever it speeds the process for solving some complex problem. Engineering students are not trained for careers in keypunch operation or programming, but they will be exposed to both in formal courses in computers and in many design courses. Here again, a weak interest in the subject does not bar you from a successful engineering career, but a fair or strong interest is an indication that

you will adopt this strong tool rather than fight it.

What about the other subjects that a high school student finds interesting? Does the fact that a student finds other subjects equally interesting mean that he or she should look for some career other than engineering? Let's continue this checklist and then examine the college counselor's views on how other subjects fit into the total picture.

My interest in	Strong	Fair	Slight
physical education is:	_____	_____	_____

An interest in physical education, especially sports, seems to be a natural one for all youth. A majority of our engineering students are avid sports fans and many have had high school varsity experience in football, basketball, wrestling, swimming, gymnastics, soccer, tennis, or other sports. Hence, a strong interest or lack of interest in physical education or sports seems to have little bearing on whether or not you are suited to an engineering career. Good physical and mental health is a great asset in completing a rigorous college career in any professional field. Furthermore, good health, a disciplined body, and the ability to meet extraordinary physical and mental demands will be plus factors for a long career in a competitive society in any professional field.

A word should be given here to the role that a physically handicapped person might play in engineering. Such persons are not excluded from a successful career in engineering, and many such individuals have progressed through college and adapted themselves to opportunities in industry. Certain types of jobs, such as field work, may be beyond the scope of a person confined to a wheelchair, but industry offers plenty of opportunities in the design, development, and research areas where a physical handicap offers no impediment.

My interest in	Strong	Fair	Slight
music is:	_____	_____	_____

Our observations are that many engineering students have a strong interest in music in all of its various forms. Many have been active participants in instrumental music, but many more have been

"stereo buffs" who have taken a strong interest in the entire range of music, from classical to folk. Some studies have shown that many mathematically oriented people enjoy classical music—perhaps some correlation exists between the structure of mathematics and the structure of music composition. Certainly, a strong interest in music does not rule out a career in engineering. To a lesser extent, the argument also applies to other forms of art.

My interest in some of the social science subjects is:	Strong	Fair	Slight
	_____	_____	_____

If we include such high school subjects as sociology, economics, political science, psychology, or geography in the social science category, you will find that colleges are giving an increasing amount of attention, in engineering course work, to this area. The reason becomes obvious: since so many engineers are to become leaders of people and corporations in their career years, we must prepare them for an understanding of the social order in which they will perform. The problems of air and water pollution, traffic control, housing, conservation of resources, etc. have strong engineering implications. The future corporation executive must know that an engineering decision in the plant may have strong effects on the community and the nation. An interest in these areas does not rule out an engineering career.

My interest in the humanities is:	Strong	Fair	Slight
	_____	_____	_____

If high school courses in language, literature, philosophy, music, art, history, and others that place greater emphasis on people than on things have strong interest for you, we can only repeat that this does not rule out engineering in your future career. In college, every engineering student is required to include courses in humanities for the same reasons that courses in social studies are included. Since many engineers become managers, superintendents, administrative officers, project leaders, and directors, they must have an under-

standing of people, of what makes them "tick," and of how to work with them. An engineer will be expected to meet people, manage people, work with people, and get along with people of all types and levels of training. This means that a liking for courses in the humanities does not rule out a future career as an engineer.

What about some of the other things that some counselors believe are indicative of a future engineer? Many of these so-called "indicators" may not be true; some of them may be partially true. Here are some of the interest indicators that frequently have been cited, especially by those not familiar with engineering as practiced today:

	Strong	Fair	Slight
My interest in tinkering with cars is:	_____	_____	_____

A strong interest in tinkering with cars could be an asset in mechanical engineering, but unless it is combined with a strong liking in mathematics and physics, this interest may be a better index of a successful career as a mechanic. At the same time, the lack of a strong interest in tinkering with cars does not rule out engineering. Some engineers do like to tinker with machinery, but there are others who prefer to work entirely with pencil and paper on analytical solutions.

	Strong	Fair	Slight
My interest in tearing apart watches, clocks, and machinery is:	_____	_____	_____

If the interest stops as soon as the machine is torn down, this might be of significance in some professions, such as salvage operations, but not necessarily in engineering. The mechanical engineer has the opportunity to be creative, to design, or to produce some useful object that did not exist before. The desire to tear apart a machine is good if the student learns from the operation what makes it "tick," and how others have put it together. But an interest in making something new is of greater significance whether it involves the use of an erector set, a drawing board, or a mathematical solution.

My interest in dealing with puzzles and riddles is:	Strong	Fair	Slight
	_____	_____	_____

Many persons inclined toward the physical sciences enjoy working puzzles, riddles, and mathematical problems. For instance, the magazine *Scientific American* and the Tau Beta Pi (honorary) magazine carry a special section to satisfy this bent among its readers—many of whom are physicists, chemists, mathematicians, engineers, and other scientists. There may not be a direct correlation between this interest and an engineering career, but the type of mind that is challenged by new problems will probably find an engineering career a most satisfying one to follow.

My interest in things far outweighs my interest In people	Strong	Fair	Slight
	_____	_____	_____

Some high school counselors assume that if students are interested in things they may be suited for engineering, and that if they do not like to deal with people, the counselor is sure of it. Nothing can be as damaging as this assumption. It is true that a "genius, lone-wolf, closet-case, inventor" might be able to work all alone in the development laboratory of a big corporation and be successful; but, by and large, engineers have to deal with people—and the higher they rise in their organization, the more important the "people aspect" becomes and the less important "things."

Persistence, rather than brilliance, is my main characteristic	Strong	Fair	Slight
	_____	_____	_____

Brilliance is a great asset, but lack of brilliance can be offset by dogged persistence. Careers in engineering are so varied that industry can eventually place a person in the best slot for his or her particular talents. The most brilliant students in the class may not go as far in their careers as the less brilliant students who have strong compensating features that industry and their colleagues value.

Engineering is a demanding profession, and the qualities of reliability, stick-to-it-iveness, and productivity on time are given strong weight in many jobs. The important item here is to look for the kind of position that best suits your aptitudes and interests.

How can we summarize this checklist? The challenges and demands of mechanical engineering encompass all kinds of people with all kinds of backgrounds and interests. In order to meet the demands of college training, a strong interest in mathematics, physics, and English is needed—and a fair-to-strong interest in chemistry and other high school subjects. Basically, the mechanical engineering departments are preparing their graduates for innovation, creativity, management, and leadership.

If the prospective student in engineering seems to possess some of the attributes that might prepare him or her for such a career, then serious consideration should be given to mechanical engineering as a lifetime career.

CHAPTER 4

WHAT EDUCATIONAL BACKGROUND IS REQUIRED?

Before we consider the best educational background for a mechanical engineer, we should make clear the difference between an engineer and a technician, or an engineer and a craftsman, or even an engineer and a scientist.

THE MEMBERS OF THE ENGINEERING TEAM

In many large companies, the engineer is not a soloist, but a member of a selected group that is designated as a "team," "unit," "group," or "task force." The leader of the group is often an engineer whose team members may include other engineers, technicians, mechanics, draftsmen, and even nontechnical personnel who have knowledge of costs or product design.

The following condensed description of the members of the team is from *The Engineering Team*, a guidance booklet prepared by A. Pemberton Johnson for the Engineers' Council for Professional Development.

The five principal types of technical team members are: craftsmen (including draftsmen), engineers, scientists, technicians, and technologists.

1) *The craftsman* typically prefers to work with power or hand tools on physical objects in their installation, maintenance, or trouble-shooting.
2) *The engineer* is primarily an innovator or creator of *new* products, processes, procedures, or systems whose interest is in:

how to solve specific practical problems (through his use of mathematics, knowledge of science and practical judgment) and how to do that economically.

3) *The scientist* is typically the theoretician, the developer of hypotheses, the searcher for truth and the formulation of broad or basic ideas, the discoverer and categorizer of knowledge whose interest lies chiefly in what occurs and why.
4) *The technician.* The engineering or physical science technician often uses the ideas or carries out the technical plans of the engineer or scientist (—installs, checks or tests, maintains and repairs, modifies and improves equipment and facilities).
5) *The technologist.* The engineering technologist is typically a practical person interested in applying engineering principles and in organizing people for industrial production, construction, or operation, or in the improvement of devices, processes, methods or procedures (—as a technically trained organizer-doer probably more often than as an innovator).

Clear-cut distinctions between the five job classifications are not always maintained in industrial practice. Certainly the technologist's function has not been clearly defined in most organizations, nor is the preparation for the function clearly stated and accepted. We have seen engineers engaged in two or more of these classifications, depending upon the project and the needs of the team. Some engineers are so versatile that they can be as theoretical as a scientist and as handy with tools as a craftsman. In any case, it is true that the *team* is becoming the working unit, whether the group is working in a large design section or in a giant research laboratory. The important point to be made in the above classification is that the academic preparations are not the same for the five groups. The engineer and the scientist require a *minimum* education of a four-year Bachelor of Science degree in an accredited engineering or science program.

TECHNICIAN BACKGROUND

In former days, it was possible for one to become a practicing mechanical engineer and to be elected to full membership in the

American Society of Mechanical Engineers without having a formal college education in engineering or the physical sciences. Even today this path is open to a capable person, whose training might have ended with a technician course but whose work experience has included a long apprenticeship and eventual responsibility for engineering work of creditable nature. This path is becoming more difficult as the professional aspects of engineering are being emphasized and as greater consideration is being given to the broad educational experience in social science and humanities now included in engineering curricula.

If, through counseling or personal choice, a student first enters a technician course and later decides to enter an engineering program, he or she may find that some of the early courses will not be counted for credit towards graduation. The student may also learn that he or she will be required to spend an additional semester or two in order to catch up with others. The move is possible, however, and the earlier a counselor discovers students with college potential, the less time will be wasted by the student.

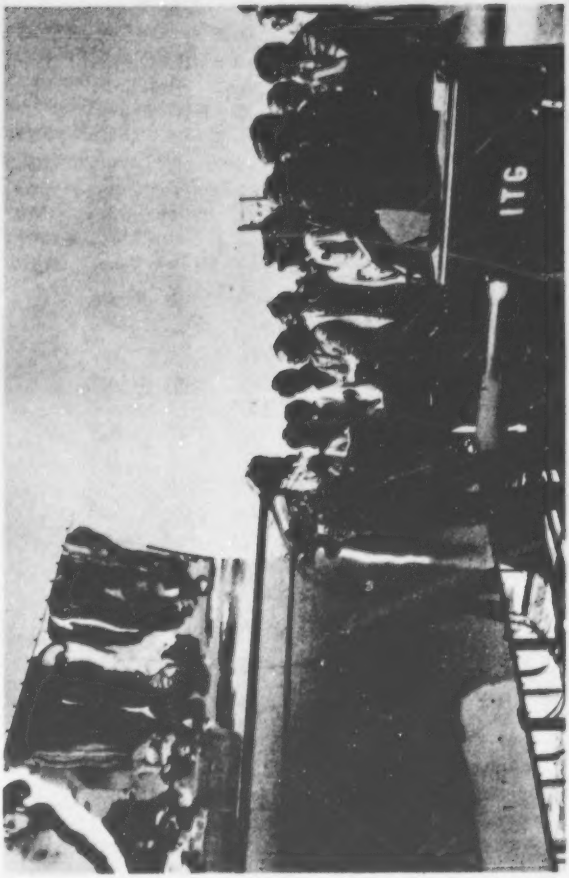
The main difference between the technician program and the engineering curriculum is that the emphasis in the technician program is on "how to," while that of the engineering program is "why." For example, an automobile mechanics course will train a student "how to diagnose the ills of an engine and how to correct the ills." On the other hand, the engineering course will concentrate on "why a higher compression ratio leads to higher thermal efficiency" and "why higher octane numbers suppress tendency for knock." Basically, technician training is excellent for learning about present-day engines, fuels, and equipment—whereas engineering training is aiming for the engines, fuels, and equipment of the future, as well. In fact, if the engineering educational background has been adequate, the graduate of the program should be able to adapt and educate himself or herself to the newer demands of chemical analysis of exhaust gases, different thermodynamic cycles, new materials for engines or catalysts, or vehicle stability. Former Dean W. L. Everitt has often referred to engineering as not just a "learned profession," but rather a "learning profession." This distinction between the technician training and formal engineering education should be understood by

high school counselors if they are to serve their students well. Many students should be directed towards technician courses if their aptitudes and their capabilities indicate that they would make their greatest contribution in this type of work. On the other hand, some students' potential is limited by technician training, so they should be urged to enroll in an engineering college.

BASIC UNDERGRADUATE TRAINING FOR ENGINEERING

The shortest path towards a career in mechanical engineering is through formal college training that leads towards a Bachelor of Science degree in Mechanical Engineering. This is basically a four-year college program, although in many cases an extra term is required by the average student. In some schools, the program requires five years of study. A list of schools offering accredited undergraduate curricula in mechanical engineering is shown in Appendix A. No two engineering schools have exactly the same curriculum. In fact, even at a given school, constant changes in curriculum are being made so that the graduate of one year is taking courses that were not included in previous years. So, we shall not attempt to describe the contents of a typical mechanical engineering curriculum in fine detail, but view it only in broad terms. Moreover, the descriptions of courses may not be meaningful to a nonengineer. Basically the subjects covered in the undergraduate program include the following:

(1) *Mathematics.* This includes courses in analytic geometry, calculus, and differential equations.
(2) *Computer Science.* One or two courses plus applications in junior and senior level courses.
(3) *Chemistry.* Usually one year.
(4) *Graphics.* One or two courses.
(5) *Rhetoric.* Usually one year.
(6) *Physics.* Includes topics in mechanics, heat, electricity, magnetism, wave motion, sound, light, and modern physics.
(7) *Mechanics.* Includes topics in statics, dynamics, and deformable bodies.



Student members of ASME on tour of Sandia Laboratories in Albuquerque, New Mexico. They listen to presentations on Sandia's solar thermal test facilities, its photovoltaic program, and its wind and energy program. Membership in an engineering society will be important to these persons later as professionals.

(8) *Thermosciences.* Includes topics in thermodynamics, heat transfer, gas dynamics, and systems, both theory and laboratory.
(9) *Electrical Science.* Basic electrical engineering.
(10) *Instrumentation, Controls, and Laboratory.*
(11) *Machine Design.* Includes mechanics of machinery, machine elements, dynamics and vibration.
(12) *Materials Processing,* including heat treatment of metals.
(13) *Social Science and Humanities.* More than 12 hours.
(14) *Electives,* including technical subjects.

The total number of semester hours varies from 120 to 140. Most engineering schools provide an opportunity for a student to begin pre-engineering studies at a junior college or a 4-year college with pre-engineering curriculum and to transfer to an engineering college at the beginning of the junior year without lost credits.

In the 1970s, the number of semester credit hours required for the four-year pre-engineering program was reduced to a minimum of 120, with a fifth-year Master's program leading to some engineering degree designation. With this change, specialized technical courses are given mainly in the Master of Science (or Master of Engineering) portion of the complete five-year program.

In recent years, a number of alternate engineering degrees are offered which also qualify one for a career as a mechanical engineer. Among the degrees offered are the following:

Engineering Science
Energy Engineering
Engineering Mechanics (these two degrees in mechanics are not to be confused with technician courses in
Applied Mechanics automobile mechanics or machine shop practice.)
Environmental Engineering
Manufacturing Engineering
Materials Engineering
Mechanical Analysis and Design
Mechanical Design
Mechanical/Aerospace
Process Engineering

Thermal and Environmental Engineering
Thermomechanics and Energy Conversion

All of these degree programs offered by accredited engineering schools require a minimum of four years of undergraduate study, and are not to be confused with two-year programs in trade schools or with courses for training technicians.

WHAT ABOUT NEWER INTERDISCIPLINARY STUDIES?

One of the interesting trends in recent years has been the rising interest in combinations of other fields with engineering. Here are a few such combinations:

Bio-engineering

Graduate studies include courses in biology, natural sciences, and health sciences—so that a career can be directed towards engineering aspects of medicine. This includes development of instrumentation and measuring devices, mechanical devices for heart, kidney, and liver functions, and surgical devices.

Bio-mechanics

Graduate studies include courses in biology, natural sciences, and health sciences—so that a career can be directed to engineering solutions of problems involving machines and human beings. For example, safety in automobiles can involve studies of impact stresses, while artificial bone material may replace fractured and damaged bone structure.

Environmental Control

Graduate study includes courses in meteorology, microbiology, health sanitation, and waste disposal—so that a career can be directed towards engineering solutions of problems related to water reclamation, air pollution, water desalination, noise pollution, and housing.

Marine Engineering

Graduate studies in the field of oceanography include courses in meteorology, geography, zoology, oceanography, and chemistry—so that a career can be directed towards engineering solutions to underwater explorations, ocean mining, ocean prospecting, ocean farming, and ocean transport vehicles.

Space Engineering

Graduate studies include courses in astronomy, high-atmosphere physics and radiation, gas dynamics, high-vacuum physics, physiology, ergonomics (the science of human behavior in relation to physical work), and geology—so that a career can be directed towards engineering solutions to space exploration efforts of the 21st century.

Others

The list of interdisciplinary studies is almost endless, since industry and government depend more and more on the solid background of the engineer, who is basically trained to be a problem solver and to enter new fields of endeavor. The best recent example of this ability to pioneer into new fields is in space engineering work. Most of the engineers engaged in this field did not have college training in rockets, missiles, astronomy, and system reliability. However, with the background they did possess, they were able to study and master many new topics and disciplines that were unheard of when they were engineering students.

COMBINED LIBERAL ARTS—ENGINEERING PROGRAMS

Many colleges provide an opportunity for a student to obtain a

background in liberal arts, followed by a topping-off in engineering. The time requirement is usually extended by about one year, and the student earns both a Bachelor of Arts and a Bachelor of Science degree.

WHAT ABOUT GRADUATE STUDY?

In the "Goals of Engineering Education" of the American Society of Engineering Education, the probable future directions of engineering education would consist of: (a) a four-year pre-engineering Bachelor's training, (b) followed by a one-year integrated Master's degree in engineering.

Even now the percentage of those continuing beyond the Bachelor of Science degree towards a Master of Science is well past 25 per cent of all graduating seniors with majors in mechanical engineering. If the "Goals" report becomes effective within this decade, some trends of the following sort could develop:

(a) Those who stop their education at the end of the pre-engineering training might serve industry in those positions where a high degree of technical capability is not required. These positions (which could be just as remunerative as the more technical positions) might include: sales engineering, plant supervising, performance testing, maintenance engineering, and distribution engineering.

(b) The number of students who will continue to the first formal degree in engineering at the Master's level will probably increase to 50 percent or more of the senior class. The first jobs in industry for these graduates will probably be in technical lines that are included in design, development, and research phases.

MECHANICAL ENGINEERS WITH M.B.A. DEGREES

Many mechanical engineering graduates seek as their second degree the Master of Business Administration (M.B.A.) degree, either

immediately after their Bachelor of Science degree or several years later. As explained earlier, the first position offered engineering graduates is based on their ability to contribute immediately to the company as engineers, whether in design, testing, production, research, or sales. Usually, therefore, if they feel that their technical background is not sufficiently deep to cope with the growing demands of the company, they will seek advanced studies in engineering subjects and in higher mathematics. Many companies are located in cities where night-school study leading towards a Master of Science degree in mechanical engineering can be secured.

If, as is commonly the case, engineers move up the corporate ladder to some degree of managerial responsibility, they discover that their technical competence is adequate and their engineering judgment is respected. Then, several years after graduation, they begin to find the need for more knowledge in such diverse areas as accounting, economics, computer analysis, public speaking, psychology, labor relations, corporate finance, salesmanship, marketing, banking, or business-letter writing. No single degree covers these diverse areas, but the need for the second phase of their professional career can sometimes be met by studies leading towards an M.B.A. degree. An engineering background and work experience provide excellent preparation for this new field of study, which is less involved with detailed engineering work and more concerned with management problems.

Some engineering graduates have started their M.B.A. studies immediately after obtaining a Bachelor of Science degree. In most schools, the M.B.A. study program consists of two years of full-time study, which is longer than the program leading towards a Master of Science degree in Mechanical Engineering. Furthermore, the opportunity for some form of financial aid for M.B.A. students is less than for those seeking a Master of Science degree. Hence, unless the student is able to finance his or her own graduate education, the more realistic program is one in which the M.B.A. study is pursued in evening study during full-time employment as an engineer.

Because of the two-year time requirement for the M.B.A. degree, some students have followed a shorter path offered by many engineering schools. These programs show similarities with the M.B.A.

program and place emphasis on Operations Research (described in Chapter 2). The second degree can be one of the following: Master of Industrial Engineering, Master of Industrial Administration, or Master of Engineering Management.

MECHANICAL ENGINEERS WITH LAW DEGREES

Every year, one or two percent of the mechanical engineering graduates in a large graduating class will seek additional training in law. The most common path is for the engineer to spend a few years in prelaw and law courses so that he or she can qualify in patent law or corporation law. The path is long and the requirements extremely high. The rewards, however, are sufficiently attractive so that a small number will endure the discipline of two demanding professions. Surprisingly enough, this seems to be a one-way street; some engineers can become lawyers, but law students seldom elect to follow up a law course with an engineering degree.

We have observed that any person contemplating a career in law should learn to read rapidly. In engineering studies, the nature of the reading requirement is such that speed reading is not required. For example, an engineering student will examine mathematical equations, chemical equations, and numerous tabular material with great care and deliberation. He or she reads a mathematical expression, ponders over each symbol, and then retains it in his or her memory—a mental process that may require several minutes to cover just one page. Constant exposure to this type of reading tends to persist even when the material is not as ponderous. On the other hand, the student in law school may be required to read pages of case material, glean the nuggets of ideas buried in the pages, and summarize the basic ideas in concise written form. One former engineering student explained his difficulty this way: "I find that I have to wade through so much garbage before I can discover the essentials." So the former engineering student finds it necessary to change his method of attack on reading assignments and to speed up his reading from the former average of 250-300 words per minute to one that is several times higher. This can be done by conscious effort at speed reading, but

the transition has been noticeably difficult for engineering students who have become accustomed to a slow, deliberate speed that squeezes all the juice from the printed page.

PREDICTIONS FOR GRADUATES IN THE 1980s

The Education Division of the U.S. Department of Health, Education, and Welfare in 1975 made a prediction for the future on the number of graduates in engineering (all branches), based on the actual degrees conferred in 1973–1974 and the trends of the previous eleven years.

B.S. Degrees. 1973–1974: 50,320. 1984–1985: estimated 60,920. (The estimate predicts a peak of 61,430 in 1982–1983 and then dropping off. These figures include about 9,400 engineering technology degrees.)

M.S. Degrees. 1973–1974: 15,380. 1984–1985: estimated 17,330 (The estimate is for a maximum in 1982–1983 of 17,830 and then diminishing.)

Ph. D. Degrees. 1973–1974: 3,310. 1984–1985: estimated 2,680 (This projection shows a levelling off after 1977–1978.)

Similar predictions made about eight years ago were not accurate. The estimates at the time predicted great increases in the advanced degree levels that did not materialize. The present predictions seem to us to be more realistic.

The percent of engineering degrees to the total degrees conferred at any time show "popularity" trends among college students. These percentages for current and projected dates are as follows:

	Current	Projected
Degrees Granted	1974–1975	1984–1985
B.S. in Eng.	5.0% of total	5.7% of total
M.S. in Eng.	5.4% of total	5.1% of total
Ph.D. in Eng.	9.8% of total	6.2% of total

The predictions of the Education Division are that the decreases at the M.S. level are made up by increases in computer and information sciences, a related field. At the Ph.D. level, an increase in the health professions and education fields is predicted. The Ph.D. level in engineering will depend upon the faculty demand in the coming decade. There are two favorable trends as far as the doctoral candidate in engineering is concerned: 1) The enrollment in engineering seems to be increasing, thus causing a demand for teachers, and 2) The large influx of engineering faculty members in the postwar period of 1945 to 1950, and later, is proceeding through the educational system as a distinct group. In the 1970s and the 1980s, this group will have served between 30 and 40 years, and retirements will take place at a large rate. This, in turn, will bring about a demand for replacements.

The earlier prediction was in error as far as estimating the number of engineering graduates for the mid-1970s, but the error was in favor of the graduates, since there were much fewer than predicted. That is, an oversupply did not exist and employment opportunities were far more favorable than had been estimated. We agree with the conclusion that was arrived at earlier:

> There are several indications that there is not now, nor is there likely to be, a real over-supply of engineers. The nature of the available jobs may be changing, with temporary dislocations of people, but there is no reason for panic or fear of prolonged unemployment among scientists or engineers.

SELECTED READING MATERIAL

"The Engineering Team," (EC 69; 13 pp. 25 cents) E. C. P. D. Publications.

"Accredited Programs Leading to Degrees in Engineering," (EC 20; 25 cents).

"Accredited Programs Leading to Degrees in Engineering Technol-

ogy," (EC 21; 25 cents).

"Career Guidance for Engineering," (EC 77; 32 pp. 75 cents).
Compilation of eight articles dealing with career guidance for the engineering team—engineer, technologist, and technician. A special reprint of *Professional Engineer* magazine, Vol. 45, No. 4, April 1975. (Chapters include: "How Employers View the Engineering Team.")

CHAPTER 5

HOW TO SELECT A COLLEGE

SHOULD YOU GO TO A COMMUNITY COLLEGE OR AN ACCREDITED COLLEGE?

Sometime during your junior year of high school you should begin the process of selecting a college. Each student has individual preferences and limitations that make the choice something special and personal. Let us list some of the options open to you.

First of all, let us explain what is meant by an accredited college. The Engineers' Council for Professional Development (ECPD) is an organization which periodically reviews the curriculum, facilities, faculty, library, and administration of an engineering department and issues accreditations for specific curriculum, such as mechanical engineering. (See a complete listing in the Appendix section of this book.) This accreditation is not given to community (or junior) colleges, although each may have a different kind of accreditation from some other educational agency. A student may start engineering degree work at a community college and then transfer to an accredited four-year engineering college at the end of the second year.

A community college may be located near home and offer a pre-engineering course of study. The advantages of going to a local college are many:

a) The cost of education may be the least expensive of all the options open to you.
b) The two-year program may enable you to test yourself in a more competitive situation than existed in high school, and to determine whether you are ready for more demanding studies.

91

c) You will enjoy minimum disruption in your life. Problems of homesickness, lack of a part-time job, and the adjustment to a large campus are not present.
d) Many community colleges offer a program that has been approved by one or more cooperating engineering colleges, so that there will be no loss of credit when a later transfer is made.

Along with the advantages of a two-year pre-engineering school are some offsetting disadvantages:

a) Many advantages exist in taking all four years of engineering studies at one school. Becoming familiar with a large campus, forming friendships early, and establishing a new routine of independent living is the usual experience of every freshman. When you postpone this transfer to the third year, you will be making a living adjustment which your classmates made two years earlier.
b) The atmosphere of a four-year engineering college is more professionally oriented than that of a two-year college. For example, many engineering schools have student chapters of national engineering societies, such as the American Society of Mechanical Engineers (ASME). These societies are open to students at the freshman level at a nominal cost, and are student run with the aid of a faculty adviser. The benefits consist of subscription to a professional magazine, a chance to enlarge acquaintances with upperclassmen, opportunities to meet chapter members of full-time professional societies, and field trips to nearby plants and laboratories.
c) The teaching faculty is oriented towards teaching professional students rather than mixed groups of students with varying career goals.
d) The overall quality of student ability is usually higher and more consistent in a four-year program when compared with a two-year course. In addition, the presence of many foreign students of high ability and intense dedication adds entirely new outlooks and friendships to the college experience.

Our experience has been that when students are expected to perform at a higher level, most will rise to the challenge. This is especially true when the entire class becomes motivated towards getting the most out of their short four-year experience.

e) Although going away to school may separate you from a comfortable home and friends, this is a part of the process of growing up. You will have less interference from parents, and fewer distractions from high school friends who are no longer going to school and have time to burn each evening.
f) The four-year engineering college has many laboratory facilities that are constant reminders of things to come. A freshman may not enroll in laboratory courses that involve sophisticated instruments and complicated equipment. However, he or she will be passing them daily and will be looking forward to the day when he or she will be a junior.

Our experience has been that good students can come out of either two-year or four-year programs. We have seen many honor students emerge from a community college background. The main questions that each student must answer are: Which is the best course for me in the long run? Can I afford the choice?

WHAT ABOUT A LARGE SCHOOL OR A SMALL SCHOOL?

A number of excellent, small engineering colleges flourish in this country and in Canada, and these have produced well-trained and informed graduates. Our long experience as graduate student advisers has convinced us that no school has a monopoly on good graduates and that a good student cannot be spoiled by a relatively unknown school, only slowed down a bit. We recall one year some time ago when the two best graduate students out of an entering class of 50 students came from two schools with which our staff was totally unacquainted. These two students gave a better performance than the 48 other graduates from a host of larger and better known schools. Incidentally, their career performances have been equally impressive—both are now administrative heads of engineering schools.

This raises the old question of: "large school or small school?" This query is not as pertinent in engineering as it might be in liberal arts studies. The reason is that most engineering schools are part of

large universities. This has been brought about by the high cost of maintaining an engineering college, as compared with the cost of a college that depends primarily on a lecture program. The equipment in engineering laboratories is frightfully expensive and becomes outmoded in a matter of a few years. Prior to World War II, for example, most mechanical engineering laboratories included Corliss steam engines, large Diesel engines, pumps, refrigeration machinery, and fans that were almost indestructible. Student experiments were conducted on these large devices year after year and equipment was seldom replaced because the units were slow-speed devices that suffered little wear. That day has passed. Most M.E. laboratories now include electronic instruments: sensors that measure pressures, temperatures, and speed; recorders that present visual pictures of changing conditions; computers, print-out devices, visual screens, and other devices that are constantly being upgraded, if not worn out from heavy student use.

The expense of maintaining costly laboratories has resulted in some reduction in experimental courses and a shift towards analytical and design courses. Our observation, however, is that students of mechanical engineering are provided as much hands-on experience with equipment as students in any other engineering curriculum.

A large school does not necessarily provide an atmosphere of cold, impersonal surroundings. In a large university, the *department* becomes the universe or the focal center of student interests, rather than the *university* itself. Lifelong friendships are formed in the laboratories, design rooms, and lecture halls where the same group of students meet daily. Many laboratory and design classes are handled on a student-*team* basis—each member of the team makes a contribution to the final design or group report. The students on the team argue, dissent, design, dissect, construct, and eventually arrive at a group conclusion. In some classes, these group reports are compared with others and defended before the students' peers. Many graduates will recall that those were the most pleasant learning experiences in their career and that real friendships with from two to four dozen colleagues from here and abroad were made during those formative years.

The large school offers opportunities for students to engage in professional activities, which can include explaining an Engineering Open House exhibit or conducting a meeting of the student technical society. In this connection, mechanical engineers certainly must be a gregarious group because M.E. departments seem to sponsor more professional societies than other departments. Many schools will have student chapters of ASME, the American Society of Automotive Engineers, the American Society of Heating, Refrigerating and Air-Conditioning Engineers, the American Foundry Society, and Pi Tau Sigma (the M.E. Honorary Society). Each chapter, with its set of selected officers, provides its members with valuable experience in conducting meetings. (A faculty adviser stays in the background to give moral support to inexperienced student officers.) In our experience, one of the main reasons that our engineering graduates have retained their loyalty to their school is that the students get to know the faculty and their student colleagues much better than they are able to do in many nonengineering departments.

In any case, we believe that an engineering student in the very largest mega-varsity campus need not be a lost soul—a computer-card identity. Those who make such claims simply do not understand the atmosphere in a professionally oriented school like engineering.

What About ACT or SAT Scores and Rank in Class?

Let's consider the process of getting into a college of your choice. Admission policies vary with each school and sometimes from one year to the next. In many college catalogs, a statement appears about American College Testing (ACT) or Scholastic Aptitude Test (SAT) scores. These tests, taken in high school, plus rank in class, are common measures of probable success in college. One or both may be used as an admission standard. These indexes have been considered as the best available, and will continue to be used until something better has been demonstrated. For those who have never taken the tests and are frightened at the prospects of doing poorly, we recommend that you look over books that give examples of previous questions. It appears to us that some students are at a disadvantage

because they have never been exposed to tests of this nature and do not know how to approach them.

Every admissions officer knows that school records and test scores may not be completely reliable. Every faculty member has met an occasional "late bloomer." These are students who have shown a mediocre scholastic record, and for some reason, known only to the student, have suddenly matured and changed their attitude towards education. Whether the change has been brought about by a period of military service, by peer pressure, by a death in the family, or by a period of hard, physical labor, these occasional "late bloomers" have surprised everybody. We feel sure that admissions officers will listen intently to the claims of such persons.

First Step for Application

The first step is to write to the Admissions Office of a school asking for information about available programs, financial aid, admission requirements, and living conditions. You should communicate your interest in engineering so that the office can send you specific information.

When to Start the Process

You should start the process at the end of your junior year in high school. We have noted a growing practice in which families plan summer vacation trips to various colleges to see at firsthand some of the facilities and meet admissions people.

What About Costs?

For most students, the financial problem is a major one. The cost of tuition, fees, books, supplies, room, board, travel to and from home, clothes, entertainment, and incidentals has increased each year. Some families have been saving for this occasion over a period of years. Others have taken out tuition insurance that provides for the four years even when the family provider dies. Many students have worked part-time, enrolled in work-study programs, or re-

ceived grants and scholarships.

This matter of financial need is such a universal one that you should not hesitate to discuss the matter with the Admissions Office. You should be ready to provide estimates of income and expenses. Detailed information about college costs is given in a free booklet entitled: "Meeting College Costs—A Guide for Parents and Students," available from: College Board Publication Orders, Box 2815, Princeton, New Jersey, 08540.

Several forms need to be filled, one of the most important of which is a Parents' Confidential Statement (PCS), which should be available at your high school. This form is *not* an application for financial aid. You may be required to fill financial aid applications that apply only to a particular college, which may mean that you will fill several forms that are essentially duplications. In any case, start early in your senior year. The deadline dates for financial aid applications are often in January or February.

If you are interested in comparative costs at various institutions, go to your counselor or school library and borrow a copy of the following books: *The College Handbook* and *Student Expenses at Postsecondary Institutions.* Both of these helpful guides, which include student budgets for over 2000 colleges, are published by the College Entrance Examination Board.

In considering the financial side of your education, be sure to read the following paragraphs about cooperative work-study programs, part-time jobs, and summer pre-engineering jobs.

WHAT ARE COOPERATIVE WORK-STUDY PROGRAMS?

Co-op programs are available at a large number of schools. Be sure to ask about them because many schools offer limited numbers of openings, but do not advertise the programs as widely as other schools.

The work-study program is a cooperative venture that is arranged between a *company* and the *college*, so that the selected student will interweave full-time study periods with work periods at the company. Frequently, five work periods are planned during a five-year

period. During the work period, the student will be paid prevailing wages and will be considered a full-time employee. The work assignment will be set by the company—frequently this may be a revolving assignment in different divisions during each work period. During the study period, the student will be on leave of absence from the company. A normal four-year course of study can be completed in about five calendar years—at the end of which time he or she will have earned an engineering bachelor's degree, acquired considerable work experience, and all without incurring debt. There is no moral obligation, but there may be an advantage for the graduate to consider the cooperating company first when a formal job offer is made by the company. On the other hand, if the work record of the student was not satisfactory, the company has no obligation to offer the graduate a permanent position.

WHAT ABOUT PART-TIME JOBS ON CAMPUS?

You have heard of many students who have worked their way through school by taking a part-time job of waiting on tables, washing dishes, delivering pizzas, and driving taxicabs. Part-time jobs may be available, especially in large communities, but you must be realistic about the matter. During the first half year of college studies, you should plan to devote full time to studies and not attempt to do part-time work. The adjustment to a new community, a higher standard of study, and a new style of living cannot easily be handled at the same time an effort is being made to earn money.

Some students persist in working even when their classroom performance is below average. In such cases, values often have been misplaced. Success in their main endeavor of obtaining an education is more important than earning money to pay for the upkeep of a car on campus. It would be better for the student to sell the car, borrow some money, if possible, and make a creditable record in the classroom.

If, after a good academic start, the idea of working part time still seems important, there are campus offices that can assist you in finding a job. One faculty colleague of ours was once asked by a pizza

parlor owner to recommend an engineering student to replace one that was soon to graduate. The owner insisted: "Be sure he's an engineering student with a B average or higher." Our colleague asked: "Why an engineering student? And why a B average?" The owner replied: "I find they are more reliable than others in delivering pizzas." Perhaps he has discovered a good indicator for success in any endeavor.

WHAT ABOUT SUMMER JOBS?

The availability of summer jobs depends upon economic conditions at the time. Many large firms have offered pre-engineering jobs to junior-class engineering students who wish to become involved in technical tasks within their capacity. The offers are not as common for sophomore students and are rare for freshmen. These summer jobs are two-way programs that give the student an insight into a future career and the company a chance to look over a possible future employee. There is no obligation to either student or employer after the summer is over. Our talks with returning students indicate that some companies create such favorable impressions that the student becomes a walking public relations person for the company. On the other hand, those students who were not provided with an engineering challenge were completely negative about the company. In any case, students should make inquiries at the college office where summer jobs are being handled.

When nothing else is available except a summer job involving hard physical labor, our recommendation is to take the job even when little mental challenge exists. Our personal experience was that three months of physical labor in a sawmill provided the greatest incentive for us to complete our education. We saw at firsthand the handicaps involved when a laborer is paid for foot-pounds of energy rather than for mental capacity.

FACTORS IN CHOOSING A COLLEGE

In years of college counseling, we have heard of every possible reason for the selection of a particular college. Some choices were based upon such stated reasons as: the success of the football team, easy access to a ski hill, nearness to a large city, the possibility of finding dates, the size of fraternity houses, etc. The faculty, of course, believes that the choice should be based on the quality of education obtainable at the school, and especially upon the quality of the faculty itself.

Perhaps this is the time to discuss the matter of the reputation of a school as mentioned by students and parents. Many excellent engineering schools have a reputation that is based upon the research contributions of the faculty and graduate students. Such reputations are of interest to graduating college seniors seeking a school that offers advanced degrees—they may not be pertinent to a high school student seeking a good undergraduate program. In many large engineering colleges, the first-year classes in physics, chemistry, and English may be handled by graduate assistants, whose teaching abilities are most variable—from extremely poor to oustanding. Exposure to a real engineering professor may occur only at the junior or senior levels. The most reliable clue can be obtained by the prospective student if he or she can talk with several advanced students in the curriculum.

Be sure that the gripes and dislikes that you hear from the engineering students are about educational matters that count. For example, complaints of dining hall food are universal and there is little that can be done to replace home cooking.

SELECTING MORE THAN ONE SCHOOL

Wise high school graduates do not place "all of their eggs in one basket." Choose a variety of schools, large as well as small, and geographically far apart. Admission policies differ with each school and can vary from one semester to the next depending upon spaces available, number of applicants, and the financial condition of the

school. Be realistic in your choice of schools. If your high school record was fair, but not outstanding, select schools with varying entrance standards, since a college with exceedingly high standards may deny applications to students with marginal records. Since most schools require a deposit with an application, it is normal practice to limit the number of possible schools to three or four.

WHEN CAN YOU EXPECT A REPLY?

If the Admissions Office of a school is reasonably responsive, a note should be received from them within about two weeks after the application has been received. This first note will probably be a receipt of the application, but may not indicate final action. Allow time for delays caused by holidays, weekends, and postal delays. The notice of admission or denial may require time, and schools differ considerably in their response time.

FINALIZING THE APPLICATION

If admission is granted by two or more schools, make a decision within a few days and notify all schools of your decision. In one letter you should indicate your acceptance of the admissions notice and would appreciate registration details. The other letters should state your plan to attend another school and your appreciation of their action. These are normal, *business-like procedures* that we expect from responsible college-bound students.

CHAPTER 6

OPPORTUNITIES FOR WOMEN

BEFORE 1970

Up to a few years ago, engineering faculty members found it difficult to promote engineering as a possible career for a woman. Even our daughters told us that engineering was not for them. In those days, a few faculty members were one of the few groups in society to realize the potential among girls graduating from high school. Most of these faculty members were aware of the great progress made in some European countries, where there were large numbers of women engineers. However, in the United States, the girls and high school counselors were not interested in engineering and considered it to be a world exclusively for men.

To some extent this was true until 1970. According to the *Engineering Manpower Bulletin* (June 1976) from which data in this chapter were selected, less than 0.5% (or only 1 out of 200 engineers) of the active engineering profession were women. This was far below the percentages of lawyers and medical doctors in the United States. Also, as shown in Fig. 6-1, the number of engineering degrees earned by women (a measure of the pipeline supply for the future) amounted to less than 0.5% until 1969. Up till 1970 there appeared to be no change in sight for the future.

THE 1970s—THE TRANSITION DECADE

Some few faculty members did try to encourage high school girls to consider engineering as a career at high school career conferences

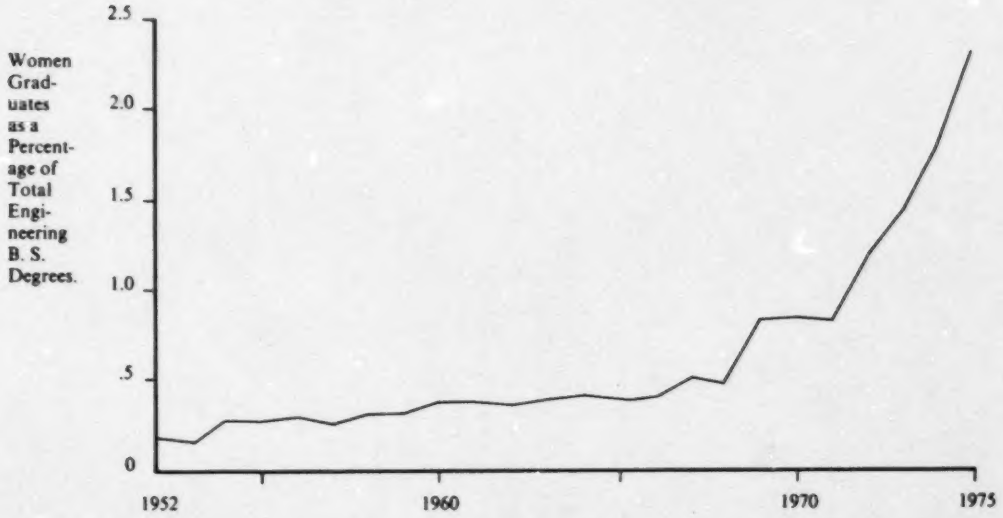


Figure 6-1. Women Graduates in Engineering.

(Source: U. S. Office of Education, Annual statistics 1952-1966
Engineering Manpower Commission surveys of 1967-1975.)

and at state science fairs. The results were most discouraging because prevailing social attitudes were against the idea. The parents were far from enthusiastic, high school counselors urged more traditional occupational goals, but above all, peer pressure among the girls themselves did little to encourage the few who might be willing to break away from tradition. The idea prevailed that a girl had to be either a car buff or a ham radio operator to qualify for an engineering career.

In looking back over the years, the single most important influence since about 1970 has been the Equal Employment Practices Act, enforced by the federal government. Now the tide is beginning to turn towards an increasing interest of women in engineering. The change is long overdue. In Europe, and especially in Russia, the number of women engineers has been a significant factor in the society.

The immediate effect of the Equal Employment Practices Act was to alert the personnel officers of industry, commerce, and the universities that the number of women engineers should be drastically increased. In the early years, a great deal of "window dressing" took place—women were hired to make a "quota" in an engineering department rather than from a need. However, the results experienced in design offices, laboratories, and factories were extremely good—the women engineering graduates demonstrated that they could hold up their end of the load. Their contributions have been impressive in those fields involving analysis, design and research.

The data in Fig. 6-1 show that after 1970 we have moved into a transition period. Not only has the total number of engineering degrees exceeded 0.5% but the growth rate has accelerated. Not until the rate attains at least 10% can the foothold be considered as well established.

The results reported in 1975 are promising. Five large engineering schools in the United States reported that from 283 to 462 women were enrolled in undergraduate engineering programs. Also, in six other smaller schools, between 17.2% and 18.7% of all engineering students were women. Furthermore, in 1975 the three service academies (U.S. Air Force Academy at Colorado Springs, U.S. Military Academy at West Point, and U.S. Naval Academy at Annapolis)

started enrolling women. These three schools slant their study programs towards engineering, so that their enrollment is pertinent to our topic. By the 1980s, therefore, women engineering graduates should begin to be a significant proportion of the total. (Incidentally, the total number of women engineering graduates in 1975 were: 878 with Bachelor's degrees, 380 with Master's degrees, and 56 with Ph.D. degrees. The numbers with advanced degrees are most impressive.)

ARE WOMEN ENGINEERS PAID AS MUCH AS MEN?

Some cynics are nasty enough to suggest that women engineers can be hired for lesser pay than for men and that this is the main reason that they are in demand by industry. The facts do not verify this claim.

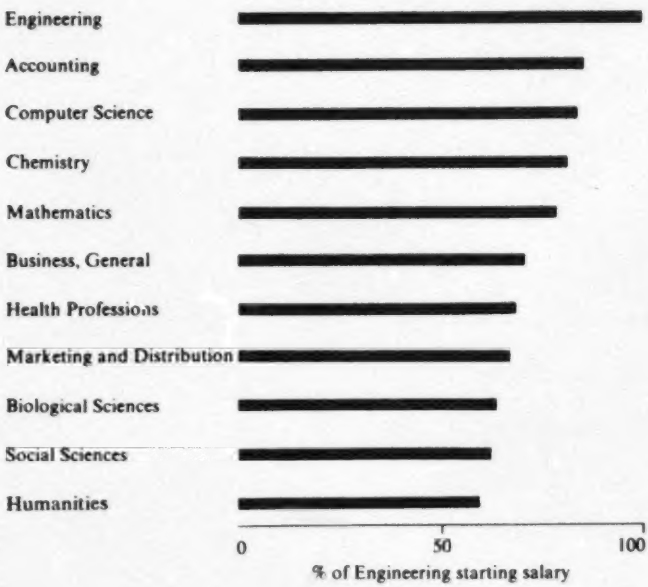
The *Manpower Bulletin* states:

> In 1975, the average salary offered to women engineering graduates at the bachelor's degree level was $1144 per month. This must be placed in proper context by comparing it not only to the average salary of $1109 offered to male engineers, but also to salaries of women graduates in other career fields. Such a comparison, shown in percentage terms in Fig. 6-2, reveals *women engineers as the aristocrats of their graduating class.* [The italics are ours.]

According to the same survey, about 9.7% of the women graduates completed the curriculum in mechanical engineering, as compared with 18.5% of the men. Truly, a continued effort has to be made to explain mechanical engineering to all high school students, and especially to the girls.

Starting Salaries for Women with Bachelor's Degrees.
(Engineering salary used as 100%)

(Source: copyright by The College Placement Council, Inc. Bethlehem, Pa. adapted from the CPC Salary Survey, Final Report, July 1975.)



WHAT DO WOMEN ENGINEERS DO IN THEIR OCCUPATION?

The best source of information about the types of work that women engineers engage in is a publication entitled: "A Profile of the Woman Engineer," as published by the 4000-member Society of Women Engineers. In decreasing order of participation, employment functions as stated by the women are:

Planning, Analysis, Consultation	30%	
Design	16%	Subtotal 46%
Administration	12%	
Research	10%	
Development	9%	
Teaching	8%	Subtotal 27%
Production, Construction, Sales, and Service	8%	
Other	7%	
Total	100%	

By comparing employment functions with the chart given in Chapter 2, note that 27% of women engineers were engaged in functions indicated to the extreme left of Fig. 2-1, and 46% in the next grouping. As expected, women engineers have been assigned to, or have gravitated towards, the left end of the job spectrum. In general, this means that their place of employment is located at the planning board, the design table, the laboratory, or the classroom and less on the factory floor, the field project, or the sales office. This does not surprise us and might be expected to be a continuing pattern in the future.

HOW FAR CAN WOMEN ENGINEERS RISE IN THEIR PROFESSION?

Since women engineers have not been practicing engineers for many years, one might expect that few have risen to supervisory or management positions. So let's look at the record as stated in the same "profiles." The following percentages are from those who returned the questionnaire:

General Management of Organization	5%
Management of Major Department, Division, or Program	8%
Supervision of Project or Section	13%
Supervision of Team or Unit	14%
Total	40%

For comparison, the *Engineering Manpower Bulletin* of September 1973 shows that 64% of *all* engineers were in these same categories. Perhaps the difference can be accounted for by the longer work experience of men in the report. The impressive part of the 40% figure for women is that this has been accomplished with a relatively small number of women engineers at a time when there was no Equal Employment Act in existence. Some might conclude that the pioneers among women engineers were the exceptionally talented and dedicated and the "cream of the crop." This is possible, since only the outstanding students tended to enroll in the early years. Time will tell whether the trends shown in the table will be continued. We see nothing to slow the trend.

MARRIAGE, CHILDREN, AND FAMILY

In the publication "Women Engineer" by Sara Jane Neustadt is an interesting observation:

> All things considered, being a woman in the college of engineering is just like being a woman in any college. You will date and party, talk and study. And unlike many women who will graduate with you, you will have the satisfaction and security of a professional career to look forward to after graduation.

In a later page appears this statement by a woman engineer:

> In general, I was accepted very well in school. I did the best I could when starting on a new class project and

most of the guys accepted me as a part of the group in a very short time.
We faculty members on the other side of the classroom desk can verify this observation.

A final set of statistics is offered by a publication of the Society of Women Engineers entitled *A Profile of the Women Engineer* (1972). From data obtained from a 1972 survey, the ages of women who responded were:

Less than 30 years of age	26%
30 to 39 years	19%
40 to 49 years	25%
50 to 59 years	21%
60 to 69 years	8%
70 and over	1%
Total	100%

Women have been in the engineering profession longer than most people realize. Those over 40 years can be considered as the pace-making pioneers of the profession.

The years of professional experience for the same women were:

Less than 10 years experience	43%
10 to 19 years	23%
20 to 29 years	23%
30 to 39 years	9%
40 and over	2%
Total	100%

The marital status of the respondents were:

Married	55%
Single	34%

Divorced	7%
Widowed	4%
Total	100%

Of the same respondents, 38% had children.

The matters of marriage, having children, and of both partners working are personal matters that are no different from those facing other professional women in current society. No doubt there are some problems that make life difficult for a married woman and her husband. For example, if an opportunity arises in another plant location, should the wife or husband leave? Should the other half of the partnership go along, hoping that he or she can find a reasonably attractive job? Or what about raising a family? If the wife decides to leave the engineering field to raise a family, can she get back into the mainstream a few years later? Will technical obsolescence make it necessary for her to take extension or night school courses to keep up her technical proficiency? These and other personal questions should be considered when planning a career in mechanical engineering.

WHAT ABOUT THE FUTURE?

We do not wish to leave the impression that life as an engineering student is easy for anyone. The engineering curriculum is a time-consuming, energy-demanding one that calls for self-discipline and effort. There have been a few "geniuses" that have floated through their college studies and made high grades, but these have been rare exceptions. Engineering students, in general, have the reputation in every school of being the busiest, the hardest working, and the most dedicated of all students. This is true for men and women.

Compliance with equal employment plans by industry, commerce, and education will continue. Perhaps more engineering colleges will be able to meet a huge demand for Ph.D.-trained faculty members. When this day comes, women engineering students will be able to see at firsthand a woman engineer in action.

We expect that employment opportunities for women will be

Drexel University Public Relations

The scene on engineering campuses is changing. Shown with two of their three children, Bill and Anne Stevens are both students at Drexel University's College of Engineering.

large, despite occasional slackening of demand because of economic recession or job dislocations. Certainly the demand for women engineers will be heavy until the employers begin to attain a better balance in their personnel. From present trends it would appear that the heavy demand will persist until the 21st century.

The present and future generations of women engineers owe a debt of gratitude to the pioneering women engineers who blazed the trail. Such trailblazers have existed in every profession, but the engineering profession has been the latest to be conquered. We quote from a woman engineer who has been there:

> I've encountered prejudice and spent much time proving myself technically competent, but have not experienced any really open prejudice. Many male engineers seem to accept me as an engineer, but wouldn't want their daughter to be one.

This was written in 1974. We can only predict that this was true of the past, but is changing rapidly each year.

REFERENCES MENTIONED IN THIS CHAPTER

A Profile of the Woman Engineer, 1972, Society of Women Engineers, (by the Statistics and Publications Committee), Room 305, United Engineering Center, 345 East 47th St. New York, N.Y. 10017. (Statistics from 346 women engineers representing 1200 members of the Society were analyzed. Because of rapid changes taking place in numbers and income, the data will become outdated rapidly).

"The MS Factor." Janet Kotel, reprinted from *Mechanical Engineering Magazine*, July, 1973. (Personalized narratives of thirteen women engineers are given, all of whom have ties with the Amer. Soc. of Mechanical Engineers).

Women Engineers. Sara Jane Neustadt, 1974. Engineers' Council for Professional Development, 345 East 47th St., New York, N.Y. 10017. (Interesting unidentified comments from fifteen women,

including three students).

"Engineering as a Profession for Women," *Engineering Manpower Bulletin*, No. 29 (Revised), June 1976. Published by Engineering Manpower Commission of Engineers Joint Council, 345 East 47th St., New York, N.Y. 10017. (Revised to incorporate new data from the 1975 EMC enrollment survey and the 1974 Society of Women Engineers profile survey.)

CHAPTER 7

OPPORTUNITIES FOR RACIAL MINORITIES

WHO ARE THE MINORITIES?

In a separate chapter we have mentioned the special case of women engineers, long a minority group in engineering. In this chapter the term "minorities" refers to four racial groups only: Blacks, or Black Americans; Chicanos, or Mexican Americans; Puerto Ricans; American Indians. This classification was made by the Planning Commission for Expanding Minority Opportunities in their excellent report, *Minorities in Engineering*. The report does not include another minority group and gives the following reason:

> Available data show that although they may be underrepresented in other professions, Oriental-Americans—including those of Chinese, Japanese, Filipino, and Asian Indian origin—are not underrepresented in engineering. John Alden of the Engineers' Joint Council states that "Orientals have long been prominent in U.S. engineering schools and in many branches of the profession." He estimates that 2.9% of U.S. engineers are Orientals, while these minorities in 1970 represented 1% of the population.

WHY THE EMPHASIS ON ENGINEERING?

The Commission's Report states in far more succinct terms what we have implied in other parts of this book. Here are some key statements:

> Any profession in which unemployment does not exceed 3%, and is usually closer to 1% (it was 1.4% in the decade 1963–1972), should be very attractive to racial and ethnic minorities accustomed to far higher rates of joblessness.

The Commission statement continues with:

> There is no question that engineering can enable previously disadvantaged students to move relatively quickly into well-paid work in professional fields. Engineers earn good livings with only bachelor's degrees while some other fields require Master's or Doctor's degrees before their graduate becomes well paid.

In another paragraph is the following viewpoint:

> An engineering degree often opens the door to advancement in management, where minorities are also underrepresented. In the manufacturing industries, 50 to 60% of new employees with college backgrounds come from engineering; and it is from this pool that the vast majority of management personnel are drawn. In fact, about half of the industrial managers in this country have a degree in engineering or a closely allied technical field.

For those seeking careers in sales and business, the Commission gives the following persuasive arguments:

> Employers use engineers in sales and operations, for example, because they find that engineers are trained to think analytically, to get work done on schedule, and to deal with problems quantitatively.... For example, a bachelor's degree in engineering is the single most desirable undergraduate degree for applicants to leading schools of business.

HOW DO THE MINORITIES FARE NOW?

The honest answer is: "Not too well." Data are not easy to obtain, but available information shows an underrepresentation in engineering fields:

Black-Americans are 11.1% of the U.S. population, but only 1.2% of the engineering profession.

Spanish-surnamed Americans are 4.4% of the population, but only 1.6% of the profession.

(Alden estimates that 45% of these are immigrants from Latin America and other Spanish-speaking countries. Thus, Americans of Spanish descent may be below the 1.6% indicated).

American Indians. The data are meager, but indications are that the numbers are extremely small.

WHEN DOES CAREER SELECTION BEGIN?

If an intensive search for prospective engineering students is to be made, the question we need to ask is: "At what year in high school does a student make a career selection?" In this connection, a report issued by the Sage Foundation (by Folger, Astin, and Bayer) and reported by the Planning Commission is revealing. The main findings can be summarized by the following statements:

a) In the ninth grade about 33% of the male students indicated career preferences in science or engineering. Four years later the interest had dropped to about 13%. Some shifts from other career fields did take place, but not in the same numbers as those who dropped out.
b) Students indicating an interest in engineering showed an earlier interest in physical science and mathematics, and leaned towards college preparatory courses.
c) High school students were not always clear about the differences in preparation and goals of an engineer and a technician.
d) Interest in engineering started as early as the seventh grade.

Family influence had much to do with the selection of a career.

e) After enrollment in an engineering college, a substantial number drop out, but in most cases the college student shifts to another curriculum, such as business administration.

f) About 40% of college engineering freshmen started in 2-year colleges. An average time of completion of a bachelor's degree requirement for all engineering students was about 4.8 years. Those in industry-college cooperative programs required another year for completion.

The preceding statements apply to *all* engineering students, and not to minorities alone. It does indicate where high school parents and counselors, as well as college faculty and advisers, should concentrate their attention if high-quality students are to be encouraged to complete their engineering studies.

WHAT SHOULD THE COLLEGES DO TO RETAIN ENGINEERING STUDENTS?

Let's talk frankly about a major problem. All too many quality students leave the engineering study program after a year or two. If a minority student drops out of the program, he or she may be inclined to feel that the reason is peculiar to the minority status. Actually, this is not so. Educators in engineering colleges have long recognized that we have always had many promising students drop out of the college. Many attempts have been made to discover the reason.

Part of the trouble lies in inadequate high school preparation and lack of background in mathematics, physics, and chemistry. Our advice to all high school students interested in any branch of engineering is to complete every available course in these subjects in high school. Then again, part of the reason for the number of dropouts from engineering is in the hands of the engineering college itself. A University of Alabama study reported by the Planning Commission shows that effective personal counseling at the freshman and sophomore level is a necessity. The engineering student needs:

> a sense of identity with the profession, a feeling of pride in being an engineer, an association with engineering faculty, engagement in student activities, and a wholesome perspective of the profession.

This ideal is not always attained. The commission conclusion regarding minority students deserves special mention:

> The attention and "Tender Loving Care (TLC)" now known to be so successful in the education of minority engineering students should not be thought of as "affirmative action" or costly frills, but should instead be recognized as mainstream, state-of-the-art educational practices, and should be provided routinely for *all* engineering students.

The commission concludes that:

> Engineering educators and professionals interested in increasing minority progress in engineering must make special efforts to provide remedial and tutorial assistance and personalized academic advising to overcome actual and perceived differences in minority students' backgrounds.
>
> . . . the most readily available pool of additional potential minority engineering students is the present class of Black college-bound women.

HOW DO THE COMMISSION'S FINDINGS RELATE TO MINORITY STUDENTS?

We have quoted from a serious study which attempted to list the problems confronting minority students in engineering. Now, how does this apply to the student? What are the prospects for a minority student who is still in high school? What should the student be doing?

We believe that *all* high school students interested in engineering

can be doing some things while still enrolled in junior and senior high schools. Here, for example, are a few suggestions:

a) *Information.* If there is a Junior Engineering Technical Society (JETS) chapter in your town, join it or write JETS, Inc., 345 E. 47th St., New York, N.Y. 10017, for information about how to form a chapter. Find out as much as you can about what engineers do and the activities they engage in. The kind of engineers we are talking about in this book do not operate locomotives or run hoists for a building project. Engineers as described in this book are not cast in one mold—they design, produce, improve, conduct research, and even teach others. Find out as soon as you can the type of activity that you would enjoy doing.

b) *Education.* Your high school education is a necessary background for college study. Make up your mind that you are going to college and stick with your pledge. Bear down on mathematics, physics, chemistry, and English in particular, but don't neglect other subjects.

c) *Concentration.* The hardest lesson that you will learn in college is *how to study.* Many college students do not learn this lesson until they are in graduate school. Up to this time, you may have been exposed to casual, easy-going approaches to reading and problem solving. The demands in college study will be most sobering to many students who have not learned to concentrate on one subject for as long as three hours at one stretch. Turn off the radio and television set, remove distracting newspapers and photographs from sight, and convert your study desk into a work space in a laboratory or a factory design office. Try to keep your mind on the study material for 10 minutes, then 20, 40, and 60 minutes. If you cannot do so now, and most of you will find it difficult, you had better start practicing. (We recall the agonies of our freshman year in an introductory design course when we were confined to a design desk and solved elementary problems in physics—for three solid hours. Each session was as grueling as a three hour examination. After that experience we could handle anything that required concentration.)

d) *Write to a College.* Many colleges have special pre-engineering programs for minority students in high school. Some schools

offer three-week or one-month summer programs that attempt to explain engineering in all of its phases. Others offer special classes in mathematics for those who need some assistance.

e) *Freshman Letdown.* You have read about engineering dropouts and about freshmen who were disappointed when they were not immersed immediately into engineering courses. You will experience a first year that is largely nonengineering. The major subjects in your freshman year will be mathematics, physics, chemistry, and rhetoric. Don't be disappointed. You will need a strong science and mathematics background that your engineering teachers at the higher level will take for granted. The best antidote for the freshman "blahs" is to get involved as soon as possible in any engineering or scientific activity available on campus or in town. You will be exposed to the perennial "griper" (we have them on every campus and at every level) but your job is to maintain faith in your objective and to let the griper's complaints vanish with the wind.

f) *Problem Solvers.* Look upon your courses as primarily a set of exercises in problem solving. You will be able to make estimates and to predict outcomes, based on analytical or experimental solutions. Look upon your courses as challenges in solving problems, and your course work can become great fun. Some day this knack for problem solving might be used to solve the problems of industry, commerce, and society. (We recall a naval architecture course in our senior year when each of us in a three-hour course designed and drew the lines for a 2000-ton cargo vessel. To this day we wonder whether the ship would have been seaworthy and stable.)

g) *Time Demands.* Some engineering students feel imposed upon when they are required to study for longer hours than colleagues in other fields. This applies to *all* engineering students. After reaching the senior year, the engineering student takes great pride in the fact that he or she has been challenged more severely than the vast majority of students, and has met the challenge. The engineering student does have longer study hours and more homework and less time for campus activities or for loafing. But the budding engineer will have learned how to utilize his or her

time and make every minute count. These disciplined habits of concentration, time budgeting, and problem solving will never be lost, regardless of what activity he or she will eventually settle into.

h) *Advanced Degrees.* Other minority groups that have been successful in engineering careers have in many cases been better trained than their coworkers, even to the extent of being overqualified. Engineering is not a profession where one can rest after four years of study—it is a career of continuing education. For example, in recent years, practicing engineers out of school for as long as ten years have had to become familiar with computers in order to stay even with the recent graduates. As you obtain industrial experience, other subjects will emerge as important to your career. Advanced degrees in engineering or business should be in your future plans.

READING MATERIAL

The book listed below is the best reference source on the subject and should be in every counselor's office.

"Minorities in Engineering—A Blueprint for Action", $1.50
American Society for Engineering Education
Publication Sales
Suite 400, One Dupont Circle, Washington, D.C. 20036

The following pamphlets are available:

"Minorities in Engineering" from ME
345 East 47th St. New York, N.Y. 10017

"Mexican-American Engineering Society"
P.O. Box 41, Placentia, California 92670

"The JETS Program"
JETS, Inc.
345 E. 47th St.
New York, N.Y. 10017

"Making It In Engineering"
E.C.P.D. Publications
345 E. 47th St.
New York, N.Y. 10017

CHAPTER 8

HOW DOES ONE GET STARTED?

RECRUITMENT OF GRADUATING SENIORS

If students enroll in accredited engineering colleges that offer courses in mechanical engineering, how do they find jobs? If the school is hidden away in a small college town, who would ever find them there? Or do they have to use vacation periods to make a tour of prospective employers?

During the past dozen years or more, excepting an occasional lapse, the least of an engineering student's worries has been employment opportunities. Just as a football scout goes to campuses with football teams and finds out about prospective professional players, so American industry has teams of people whose sole business is to visit each engineering campus to interview seniors, juniors, and graduate students for the purpose of discovering talent.

At most engineering schools, the demand for graduates has been so strong that a separate office is maintained by the college for bringing the seniors together with interviewers. In recent years, from 500 to 700 large companies have sent interviewers to the larger schools for periods ranging from one day to a week; in some cases, the interview team may be composed of six to a dozen individuals who may represent different segments of a large corporation. For example, the Bell System team is composed of interviewers from the Western Electric Company, Sandia Laboratory, Bell Laboratories, Long-Lines Division, the regional Bell Telephone Company, and other separate and interlocking parts of the larger Bell System. These are well-trained and responsible interviewers, headed by men and women from the personnel departments, but assisted by company

engineers who had their initial training at the school that is being visited.

How does the engineering student arrange to meet some of these personnel people? The following is a fairly typical procedure:

Step 1. *Contact.* The company personnel officer writes directly to some person or office on the campus. Many professors receive direct appeals by letter and telephone from owners of businesses who want to obtain the services of a mechanical engineering graduate. The larger companies have learned that the best procedure is to utilize the special facilities established at the school. Hence, their first contact is with the Placement Office.

Step 2. *Data.* An Engineering Placement Office is commonly found in many engineering schools. In a smaller college, engineering placement might be handled with all other placements at a central campus office. The Placement Officer is the go-between who serves the student and industry.

The company Personnel Representative arranges a mutually satisfactory interview date with the Placement Office. Because of the hundreds of personnel interviews that must be handled in a relatively short period of the school year, the Placement Officer will restrict the number of companies arriving on the campus on any given day or week—so that housing, meals, interview rooms, and schedules for the interviews can be handled effectively.

Step 3. *Information.* Company brochures are sent ahead to the Placement Office. These informational brochures describe the company, the number of its divisions or affiliates, the products manufactured, or the services offered. They also describe the locations of plants and offices, the geographical features, the financial record, and the company's future prospects. These brochures, consisting of hundreds of different types, are found in quantity at the Placement Office so the students may examine them if they wish. This form of selling a company name is a difficult one if the company is not known for consumer products. For example, Schlumberger Ltd. has an excellent reputation as a firm engaged in discovery and logging of oil wells by electronic instruments, and offers unusual opportunities for those interested in adventurous travel all over the world. Unfortunately, few students have heard of the company or the na-

ture of its services.

Similarly, many mechanical engineering students are not aware that a firm like Monsanto Chemical Company or duPont Company employs as many mechanical engineering graduates as chemical engineering graduates, or that mechanical engineering graduates are sought by General Foods, the Scott Paper Company, the Collins Radio Group of Rockwell International, the Gulf Oil Corp., the Anaconda Company, etc. The battle for recognition by the nation's thousand or more largest firms is a real one, so that every type of advertising media is employed in order to attract the attention of mechanical engineering seniors.

Some companies employ a "bird-dogging" technique, in which a former graduate of the department visits the campus ahead of the interview team to visit with the faculty and to obtain suggestions about which students should be invited for interviews. Some advance people will select a dozen or more names, so that company literature can be mailed directly to the students.

Many companies have provided for summer jobs for junior students. While working at these jobs, the students are placed in a well-planned program that will bring forth their talents and show them the challenges of the particular firm. The word-of-mouth advertising summer term employees bring back to the campus will affect greatly the later success of the company in attracting students to be interviewed.

Step 4. *Data Sheet.* In many schools, each graduating senior fills out a Data Sheet during the first semester of the senior year. This sheet provides pertinent information about birth date, home address, high school and college education, student activities, faculty references, honors, and many other personal items.

At some schools, a central reference office maintains a file that can include faculty evaluations or ratings, scholastic records and other confidential material. Normally, the student authorizes the release of material to persons whom he or she designates.

All companies are not seeking the same sort of engineer. In fact, a large company might be looking for several different types of people; those who are research oriented as well as those who might qualify for engineering sales. Consequently, graduates with less than

top scholastic ranking have a good chance for suitable employment, as long as they can show that they have the personal characteristics that will contribute to the success of the company.

Step 5. *Schedule.* An interview schedule sheet is posted in the Placement Office at the same time that notices are placed at various spots on the campus announcing the coming of the company representatives. The announcement may indicate that the company is interested in mechanical engineering graduates at the Bachelor's and Master's levels, and that opportunities exist for the design, development, or production phases of the business. Mechanical engineering graduates are in such demand by companies that if 450 firms visit a large campus in one semester, more than 75% of them will be seeking mechanical engineering graduates.

Senior students decide which companies they would like to interview, and sign their names for an interview to be conducted during some free hour at some future date.

Some students confine their interviews to six to eight companies; some interview as many as a dozen or more. The college imposes no restrictions, since the interview procedure is arranged as a convenience for the student and the companies, and any transaction that occurs is a private affair between interested parties. Most faculty members refrain from offering advice to students on which companies to interview or which to choose. If an interest in power generation is indicated by the student, the faculty member might suggest several companies and suggest that the student do some homework before the interview and read available company literature.

If the schedule sheet for a given company is completely filled by the time the senior arrives at the Placement Office, arrangements are frequently made for special handling of the case.

Step 6. *Interview.* Most students manage to do some homework before the interview, and learn about the company from the brochures deposited in the library of the Placement Office. The actual interview is a private conversation between the student and one or more recruiters, one of whom is often an engineer. The company representative describes the company, the challenges, and the opportunities. He or she will want to know what the senior is seeking in location, type of work, and compensation. During the interview,

which may be as short as 15 minutes or as long as one hour, the employer representative is "sizing up" the student to determine whether the interview should be followed by further negotiations or be terminated at that point. Practically all of these interviewers are experienced recruiters, but since they are human, they do not always evaluate students in the same way. The faculty urges students to be as "natural" as possible and to learn from this interesting experience, which may have profound effects on their entire careers. Neatness and good grooming never offended any interviewer.

Step 7. *Inventory.* The employer representative will seek additional information from the faculty about those students that have been interviewed. The representative is interested in a student's potential for growth, strong points, any weaknesses that may exist, and ability to communicate ideas. Some interviewers will ask about the student's academic record, participation in student technical societies, college activities, signs of leadership, financial support, reliability, and drive.

In the meantime, the student will also be taking inventory of those companies that interest him or her. The student will question classmates about their experiences with the company. Faculty members may be asked about their knowledge of the industry or about the reputation of the company.

Step 8. *Visitation.* Many companies will send an invitation to selected students to visit a company office or plant, with all expenses paid by the company. The interviewer's selections will have to be confirmed by the operating group at the plant or office. The company interview trip is a two-way proposition; the student is being looked at by possible future colleagues, and the company is being inspected by a possible employee. If a good match has been made, the opportunities that the company offers seem most attractive to the student at the same time the company personnel decides that the interviewee would make a good addition to their team. If a good match does not occur, it is often neither the fault of the student nor the interviewer.

Step 9. *Offer.* Assuming that a good match has been obtained, a definite offer of position, salary, and benefits is made, occasionally at the conclusion of the plant visit, but commonly either in writing

or by phone after the student returns to his campus. Many students are confronted with several attractive offers, each of which has some distinctive feature. If the student has selected a variety of industries for interview, rather than one narrow field, the offers can be extremely diverse. He or she might have to weigh the advantages and disadvantages between a career in an automotive company, a manufacturer of printing machinery, an electrical power utility company, a manufacturer of plastics, or a consulting engineering office.

The faculty remains aloof from this decision-making process, since it is a personal decision that only the student should make.

Step 10. *Decision.* For reasons best understood by the student, a selection of position is made that has great appeal at that particular time. A review of the reasons given by seniors of a recent class in their career choice shows a wide variety of responses, as follows: type of work, location, salary, opportunity for advancement, training program, opportunity for graduate study, worked summers for company, company reputation, company personnel and others in descending importance.

Step 11. *Assignment.* Graduating seniors notify the company personnel officer of their decisions. At the same time, they send letters of regrets to other companies who have made offers.

The students can return to their studies with a major decision completed and can concentrate on completing their academic requirements for the degree. The personnel office of the company will send details of the first assignment: where they should report; whom to report to; the nature of the first assignment; the training program, if any; and details of housing.

Many years ago, training periods of from one to two years were common. During these training periods, the new employee was moved from one position to another every few months. Currently, training periods are short, and the new employee is placed in a position where he or she becomes a part of the operation as soon as possible.

Step 12. *Investment.* Most graduating seniors realize that they do not know everything, and are apprehensive about their ability to do something constructive in engineering work. The large industrial firms, through long experience, do not expect new employees to

"earn their keep" during the first year. They realize that they are making an investment which, if their selection has been sound, should pay off later. A new employee is like a "rookie" on a professional football team—he or she is "raw," but he or she has potential. The study habits the graduate has acquired during the arduous academic career will stand him or her in good stead in a future career. He or she may never utilize some portions of the academic training during an entire professional career, but he or she will never forget the hard-nosed discipline that was required as an undergraduate engineering student to dig out facts, to assemble them in some logical order, to utilize creative and imaginative powers, and then, finally, to create something workable within a time limit.

THE SEASONED ENGINEER SEEKS A POSITION

To one who has yet to determine a life career, any discussion about how a seasoned engineer goes about changing a job may seem premature. However, some aspects of the decision-making will be valuable for any person at any point in his or her career. One of the best step-by-step recommendations along these lines was presented by Mr. George Fried, vice-president of Greiner Scientific Corporation (*Mechanical Engineering*, Nov. 1970, pp. 77–78). A condensation of the original notes is offered here:

> *Self-Analysis.* Ask yourself: "What do I really want?" Is responsibility more important than money?" Am I really flexible as to location? Do I prefer a large or small company?" Measure your current job against this analysis. You may decide to stay put.
>
> *Preparing the Resumé.* A resumé is not written to get a job, but to get an interview. It should not be too long—rarely more than two pages. Be specific about your experience.
>
> *Attack Strategy.* You have to seek out a demand. Expect to spend a lot of time and some money. Look at it as an investment.

First Thrust. There are several ways contact can be made between you and your prospective employer: follow them simultaneously.

(1) *Read advertisements.* In answering ads, write a short letter and enclose your résumé.
(2) *Mail campaign.* Conduct a mail campaign either directly or through a management consultant (whose job is to fit a person with a company).
(3) *Management consultants.* Acquaint yourself with them.
(4) *Own advertising.* Pick a good headline, leave plenty of white space in the ad, give a box number.
(5) *Personal contacts.*
(6) Consult *your college placement office* for help.
(7) Read the Tuesday edition of the *Wall Street Journal* for management openings available.

Interview. Interviews don't come easily. If all your efforts result in 5 to 10 percent success, consider yourself well on your way. Be neat and punctual. Expect to fill out a lot of unnecessary forms which may be part of the corporate routine. Do not sell yourself as something you are not. Do not abuse your present employer. Meet your prospective colleagues, visualize yourself in the position, and try to anticipate whether or not you would be happy there.

Follow-Up After Interview. Call your references and notify them about the interview so that they are made aware that they might be called by the company. Send a thank-you note to the person in the company who arranged the interview.

When the Offer Comes. Compare the job offer only with your present job or with other firm offers. There is no such thing as a perfect job. Try to get an offer in writing and confirm your acceptance by letter.

How to Quit. If you don't now have a job, you are ready to go. If you do, observe some basic rules. Don't burn your bridges behind you regardless of how unhappy you

were at the job or how badly you think you were mistreated. Give a reasonable period of notice in writing—and in it stress the challenge and responsibility aspects of the new position as your reason for departing.

WHAT COMPANY PERSONNEL PEOPLE LOOK FOR

What are personnel people seeking in the graduates of engineering schools? Surely, every student in class cannot be in the top quarter of the class. Each year the faculty is continually amazed that every student in the class is placed in some position that seems to be mutually satisfactory to the graduate and the employer. A large company, such as General Motors Corporation, may be seeking a wide variety of people—those with excellent academic records in basic science subjects for their research laboratory; those with possible talent for innovation and creativity for their development division; individuals who appear to be potential production managers for their production areas; and those with a possible flair for sales engineering for their engineering sales group. Thus, a company may seek students in the top ten percent of their class as well as those who happen to be in the lower half of academic performance. The personnel department's function is to place round pegs in round holes and to obtain a good match between the openings in the company and the best available talent. Although a slight edge in initial offers may exist for the student in the top quarter of the class, no assurance exists that he or she will progress as rapidly as another in the lower half of the class. The important matter, from the standpoint of graduating seniors is that they have the opportunity and the choice of making a selection from a wide variety of possible careers. If any fault exists in the final match, it is because the senior has made a decision based upon a limited evaluation of what he or she thought was wanted and how much effort was made to find the best opportunity.

WHERE GRADUATES GO

Where do graduates eventually go? Those from a large engineering college scatter to the four winds. Some prefer their home state, for family reasons. Others seek out-of-state positions for the same reason. Some prefer large cities, and are attracted by the bright city lights like moths to a candle. Others prefer a small town and a small company in which they will not be lost in the crowd.

Some young engineers like a large company because of its stability, better facilities and, eventually, larger opportunities. Others seek a company which at some distant time might offer them chances to become a partner or part owner. Dollars alone do not always sway a senior in the choice of a job—although, given an equal opportunity with two companies of like output, the initial salary will influence the senior towards the higher-paying position.

Some seniors consider the aerospace industry an exciting prospect; others consider such firms as unstable in future prospects. Some consider travel a desirable ingredient of their new job; others prefer to stay at home and spend time with their families. Only a senior can explain the real reason why he or she chose Company A or B or C. The faculty keeps its nose out of this personal decision.

The process described above is not the only method for future placement. Some students rely upon offers that come directly to faculty offices, examine the want-ad columns in the newspaper, or utilize the services of an employment agency or management firm. But most seniors prefer the convenience and the professional service offered by the engineering or university placement office.

JOB SATISFACTION

Many myths are circulated about the engineering graduates of recent years, so that data based on a large-scale study are of interest. The College Placement Council of Bethlehem, Pennsylvania, published a study of 40,000 graduates of the classes of 1962 and 1965. As reported by the editors of "Engineering Education" (ASEE Journal, December 1970):

> The major findings show that there is nothing approaching a mass exodus of college graduates from business or industry because of disenchantment; that the cream of the crop is shared somewhat equally by large firms, schools, colleges, and research organizations; and that there is an impressive record of job satisfaction.

According to the College Placement Council, the myth about large firms not getting their share of bright graduates because more students with low grades than with high and medium grades preferred employment with large firms has been shattered. In actuality, more of the better students wound up with large firms; for small firms the reverse was true.

PEAKS AND VALLEYS IN DEMAND FOR ENGINEERS AND SCIENTISTS

One basic fact emerges from the employment picture—that the demand for engineers and scientists varies from "unusually strong" to "modest" over a long period of years. Our story would not be complete without reference to the peaks and valleys in demand caused by economic boom and financial depression. It is true that all segments of business and industry are affected, and that a large number of people in business, trade, and the professions are affected adversely when the economic prosperity of a region is temporarily retarded. Engineers, scientists, and mathematicians are not immune from these changes in employment demand.

A firm by the name of Deutsch, Shea, and Evans has conceived the Engineer/Scientist Demand Index, which is based on data from 41 publications, including newspapers, in 20 major market areas and a wide variety of technical journals. The amount of newspaper advertising for employment of engineers and scientists is used as an index of demand. The index has shown some wide variations as follows:

1961 Base Period	Index of 100.0
February 1964	69.1

May	1966	219.0
May	1969	116.0
May	1970	58.6
May	1971	42.5
May	1975	67.7
May	1976	107.7

During the last 50 years, two major and two minor depressed periods of engineering employment have occurred. In the period of 1930 to 1935, following the stock market crash, American industry suffered its greatest period of business depression. Economic conditions were at a low ebb; investment capital was lacking; businesses were retrenching instead of expanding; and many engineering graduates of the period found themselves desperately searching for jobs, along with all other graduates and nongraduates of all fields.

Many engineering graduates who were unfortunate victims of timing in the early thirties never did return to engineering at a later date. The business depression of the early thirties (and it was a searing experience for all those who were in the employment market at the time) was followed by a business revival of the late thirties. This, in turn, was succeded by extraordinary demands of the war years. So for more than 20 years the demand for engineers exceeded the supply.

The next down period of business, which lasted for a much shorter period, occurred in the early fifties. Engineers graduating during this period found fewer offers to consider. Some prophets of doom predicted that engineers would be in oversupply for many years. But, within a year the situation changed and employers were frantically renewing their search for engineering talent.

The recession in early 1970 was especially severe in the aerospace industries and in certain defense fields. For example, when the man-on-the-moon venture was successfully accomplished, the federal funding to NASA was drastically reduced, and many aerospace and electronics firms found that few development contracts were being issued. This meant the discharge of many highly competent engineers and scientists in those areas where billions of dollars had been poured in during the early 1960s.

The depressed period of the mid-1970s was world-wide and was the direct result of the fourfold increase in oil prices by the producing nations. In the United States, a sharp reduction in defense spending followed the end of the Southeast Asian conflict. These twin jolts to business stability caused employment to decrease rapidly. In 1975 the tide of business activity seemed to have turned again, and the first group to notice the employment demand were those in engineering fields.

Unfortunately, there is no assurance that similar situations will not arise again in some other cyclical industry that depends upon government subsidy or the whims of political leaders for its existence. To some extent, those who entered the aerospace industries in the 1960s did so with their eyes open. Many times the fortunes of individual aerospace manufacturers decreased when a big contract was awarded to a competitor, and a transfer of engineering talent followed the contract winners. The main difference in early 1970 was that all aerospace contracts were reduced, so that those who were released found that the usual avenues were no longer open.

Regardless of the field of employment, a major business depression of the sort experienced in the early 1930s is difficult for an individual to prepare for. Perhaps those who place prime importance on job security should consider employment in the less cyclical and more basic industries. These would include, among others, such industries as electrical power generation, food production, petroleum, chemical, and basic manufacturing.

The experience of the past decade has shown that glamour industries, with their unusually large input of federal funds for research and development, may offer more exciting and difficult technical challenges. But they run the risk of up-and-down financing, depending upon company success in obtaining a contract. Those engineering graduates who join firms with cyclical business trends should expect larger monetary rewards than those entering more stable industries. Obviously, we are not recommending that all engineering graduates should seek only those positions where stability of employment is assured. Risk is the very essence of life, and one cannot go through life without taking some risks.

In spite of temporary "down" years of demand for all types of

employment, the long-range trend of demand for engineers remains strong. This is especially true of mechanical engineering, which is not as specialized as some other fields of engineering, and graduates have an opportunity of moving into basic industries as well as into cyclical fields.

SALARIES OF BEGINNING GRADUATES

What is a beginning mechanical engineering graduate paid? In view of inflationary trends, and because of the shortage of engineering graduates, the starting 12-month salaries have been steadily increasing. Any figures on current salaries given at the time of printing of this book may, therefore, not accurately reflect the rates prevailing at a later date.

Even during a period of economic recession, the salaries of beginning engineering graduates showed an increase over the preceding years. For example in the 1970–1971 recession, engineering opportunities decreased noticeably, but the starting salaries of the fewer available openings were higher than in previous years. Apparently, the decreased demand in some industries did not affect the salary scales of the companies that were seeking talent.

The data in the accompanying table show that within a given branch of engineering, wide diversity exists between industries—and within a given industry. The items worthy of special attention are as follows:

a) The wide variety of prospective employers is indicated by the listings on the first column. These are nationally determined data covering mechanical engineering graduates of June 1976 only. Even a few offers from banking and merchandising were listed.

b) The top 10 percent and the low 10 percent offers were not included, since some of them are exceptions that may be misleading. For example, a graduate who is employed by a family-owned firm may receive a salary that is not in line with prevailing rates. Also, those who accept an unusually low offer may do so with the knowledge that the region is known for its low

Westinghouse

Specialists at the construction site install test reactor at a Fast Flux Test Facility, Richland, Washington.

living cost. Salary values are not comparable, as anybody who has traveled widely in this country recognizes. Some large cities have large tax rates or large transportation costs or high automobile insurance rates or high housing costs that should be compensated for by a higher salary.

c) Even the average offers are subject to change from one year to the next. In other words, a difference of a few dollars between one industry and another is not significant.

d) The number of offers shows industrial demand for a given year and is an interesting barometer of business prospects for that industry in coming years.

Now, if the average of all of the preceding values is represented by one figure for that year, and the same averaging is done for a number of years, data similar to the second table can be obtained. These data are quoted from the extensive compilations of The College Placement Council, Inc. of Bethlehem, Pa. 18001.

Some interesting trends can be observed from these national figures, as follows:

a) A consistent increase was observed during the time period, which was characterized by steady inflationary trend in money value.

b) Master's degree candidates were offered approximately $130 more per month than Bachelor's degree candidates.

c) Doctoral degree candidates received offers of approximately $350 more per month than Master's degree candidates.

Although offers of other engineering disciplines are not shown, the values shown below were generally characteristic of all disciplines. The trends of the past do not give indication of the future; if inflationary trends continue, the trend will probably continue upwards.

The same information is shown in graphic form, together with data for two-year and four-year technology graduates.

Monthly Salary Offers — National Averages

(From College Placement Council. CPC Salary Survey A Study of 1975-76 Beginning Offers, July 1976).

For Mechanical Engineering Graduates Only, Men and Women

By type of Employer	Number of Offers	High Offer	Low Offer	Average Offer
Banking, Finance, and Insurance	12	—	—	$1005
Merchandising and Services	6	—	—	1149
Aerospace, Electronics, Instruments	435	$1278	$1060	1169
Automotive and Mech. Equipment	369	1299	1045	1172
Building Materials Mfrs. and Constr.	159	1308	1014	1161
Chemicals, Drugs, and Allied Prod.	576	1348	1172	1260
Electrical Machinery and Equipment	311	1248	1080	1164
Food and Beverage Processing	32	1259	1075	1167
Glass, Paper, Packaging	113	1284	1094	1189
Metals and Metal Products	346	1285	1091	1188
Petroleum and Allied Products	535	1404	1174	1289
Research and Consulting Organiz.	122	1274	1046	1160
Tire and Rubber	99	1218	1108	1163
Utilities—Public (inc. Transport.)	280	1227	1029	1128
Government—Federal	83	188	924	1056
Government—Local/State	5	—	—	1113
Nonprofit Organ. and Educ. Inst.	1	—	—	1052

Note: Highs and lows shown represent the limits within the 80 percent of range of offers (not acceptances). The averages are for total offers reported (not limited to the middle 80 percent). Highs and lows are not calculated for fewer than 20 offers. For complete information, write to The College Placement Council, Inc. of Bethlehem, Pa. 18001.

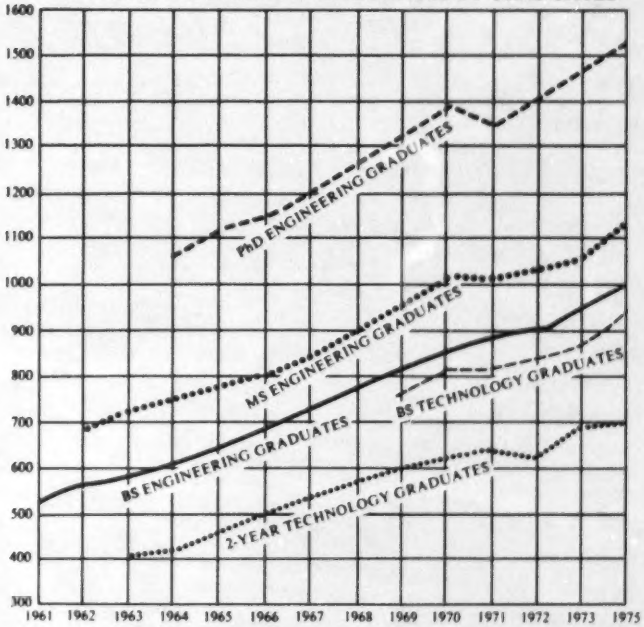
The beginning salary data reported are based on offers (not acceptances) to graduating students in selected curricula and graduate programs during the normal college recruiting period, September to June. The Survey covers job openings in a broad range of functional areas, *except teaching*, within employing organizations in business, industry, and government. The data are submitted by a representative group of colleges throughout the United States.

National Average Monthly Salary Offers
(For Mechanical Engineering Only)

Year	Bachelor's degree	Master's degree	Doctoral degree
1961	$ 541	$ ——	$ ——
1962	564	692	——
1963	592	722	——
1964	614	743	——
1965	635	765	1,116
1966	670	799	1,136
1967	720	852	1,212
1968	768	906	1,282
1969	820	954	1,309
1970	867	1,008	1,370
1971	881	1,019	1,278
1972	894	1,030	1,381
1973	922	1,069	1,418
1974	1,001	1,138	1,479
1975	1,122	1,274	1,624
1976	1,197	1,341	1,687

(From *The College Placement Council Salary Survey*. Data combined for men and women. Information on women's salaries for Bachelor's degree candidates is given in chapter on Women Engineers.)

AVERAGE MONTHLY STARTING SALARIES OF NEW ENGINEERING AND TECHNOLOGY GRADUATES



(Source: Engineering salaries adapted from annual surveys by The College Placement Council, Inc. Technology salaries from annual surveys by the Engineering Manpower Commission.)

CHAPTER 9

WHAT ARE THE PROSPECTS FOR ADVANCEMENT?

GRADING CONTINUES AFTER SCHOOL

What can one say about the prospects for advancement in the mechanical engineering field? Some people advance in spectacular fashion. Others do not. Some get the breaks in life that come from being the right person in the right place at the right time. Others may be equally capable, but because of poor health, trouble at home, or an abrasive personality, find that advances are slow.

In viewing the progress of hundreds of graduates over a long period of time, we have observed that the "typical" mechanical engineering graduate requires at least a year or two to find his or her niche in the organization and to become acquainted with the special terminology in use, local practices, and the names of the right contacts to call when information is needed. Even a seasoned faculty member finds that the commonly accepted terminology in an industry can be most confusing. For example, model numbers will be spouted off as "XB-707 C," which means something very specific to the old-timer in a plant, but is merely a collection of numbers to the newcomer. The initial contribution of new graduates to a company is their engineering know-how, whether it is making a new design, testing a new product, or helping a complex organization to function smoothly. They are definitely not selected as a "manager" at this stage. They become part of a team in a large organization—and are expected to make their own small contributions to a new product, or to maintain production schedules or to function as research engineers.

Many students think they will no longer be graded after they have graduated from school. This is far from true. In most organizations, a constant review of each person's capabilities, production, and assumption of responsibilities takes place routinely, even though the young engineer may not be aware of this scrutiny by superiors. In some large organizations, this review may be a formal one, in which the supervisor is required to submit in written form (annually) an estimate of each person's worth to the organization. In a smaller company, if the organization is on a less formal basis, the management soon becomes aware of the contribution each employee is making.

Large companies say they are constantly on the search for potential managers—persons who will accept responsibilities, those who are able to weigh all the facts and make the right decisions, those who are able to work with and lead people. Former President Milo N. Brisco of the Standard Oil Company of New Jersey (now Exxon) summarized the viewpoint of management during a panel discussion with students (*The Lamp*, winter 1970, V. 52, No. 4, p. 8) when he said: "We spend an enormous amount of time combing through our organization for people who are creative, imaginative, innovative. That's the sort of person we try to promote—one who is willing to take risks and responsibility and adapt to change. So it seems odd—this conviction that you have to conform—when we spend our time trying to find people who don't conform in order to promote them."

In following the careers of "typical" mechanical engineering graduates, the first advance to a position such as "group leader" occurs between the third to sixth year, and to "project manager" between the fifth to tenth year. Although some engineers prefer to stay in purely technical positions, more than half of the graduates find that at the end of about the tenth year they have moved away from the purely technical side of engineering projects and have made a shift toward management. Their experience and know-how enable them to make decisions that mean profit to the company. These engineers may lose sharpness with the computer and mathematics, but they are able to follow the detailed analysis submitted by younger engineers. Above all, they find it necessary to communicate with top management verbally and in writing, and at this stage any limitations in

communication skills can hold back future progress.

THE FIRST JOB MAY NOT BE THE ONLY JOB

The engineering graduate's initial choice of a company may not be the one at which he or she will spend an entire career. On the average, an engineering graduate works with two or three different companies, sometimes in widely diverse industries. It is true that a large number of graduates do start work in a company that suits them perfectly—a place where their increasing competence is recognized. Fully half, however, may wander from their initial assignment for a variety of reasons varying from "incompatibility with management" to "higher rewards in another company," "a more stimulating challenge," or "a more agreeable community in which to raise a family."

In this connection, the following report will support some of the statements above. Statistics from "The College Graduate: Turnover and Mobility" by the College Placement Council (from a nationwide survey of 30,000 graduates in all disciplines) show that within three years more than half of the male college graduates and four-fifths of the women left their first employer. Some of the other findings were revealing as well as surprising. For example, large firms had a better record than small companies in retaining college-trained employees; engineers, the most sought-after type of graduates, made the fewest job changes; and graduates with higher academic standing proved to be more stable in terms of turnover than those with lower academic performance.

Although the degree of satisfaction with the working environment has a significant relation to turnover, the much-discussed conflict between the developing "social values" of the student and the actual work experience did not seem to materialize. "What does become evident, and has not been noticed in discussions of turnover on the part of the recent graduate, is the apparent change in values that takes place as the result of work experience and increasing responsibility. Three years after graduation, the reported reasons for turnover tend to be away from the social values toward the more materialistic ones of money and advancement."

The latter conclusion is not surprising, since the idealism of a young graduate is gradually diminished as the realities of the everyday world become apparent and the responsibilities of supporting a family weigh more heavily.

THE MANAGEMENT TEAM

After a few years, many mechanical engineering graduates are included in the management team. An article prepared by the Engineers' Public Information Council claims that today most graduate management-business classes are made up of a large percentage of engineers, and that an engineering education will be to the 70s what a liberal arts education was to the 50s. An article in *Fortune* magazine predicted that by the year 1980, 75 percent of the corporate officers in the United States would come from engineering backgrounds.

Interestingly enough, this viewpoint of the future role of engineers is worldwide. Sir Owen A. Saunders, Vice-Chancellor at the University of London (*Engineering Education*, Dec. 1970, p. 79ff.) reviewed trends in Europe, and he stated:

> Turning now to general trends, there is no doubt whatever that since the war all countries have had in common a strong feeling of the importance of reviewing their methods of engineering education to try to provide engineers *suitably qualified for the management and staffing of modern engineering industry*, especially in view of the rapid changes which are occurring everywhere as a result of new developments in science and technology. New techniques of design and production are emerging everywhere, and indeed whole new industries, such as computers, control engineering, nuclear power, and many others, have grown up. [The italics are ours.]

The particular title that the management-oriented engineer holds

may be descriptive of his or her duties and responsibilities, such as:

Project Director	Consulting Engineer
Research Director	District Manager
Superintendent	Supervisor of_____
Sales Manager	Section Head
Production Supervisor	Department Head
Branch Manager	Design Chief
Vice-President in charge of	Personnel Director
Program Coordinator	Traffic Director
President	(for distribution of products)

Perhaps because the mechanical engineering graduate is acquainted with production processes and has also had comprehensive training in creative design, a larger proportion of management people have been selected from this group than from other branches of engineering. Some have assisted themselves in this transformation by enrolling in graduate courses during their early years of industrial work. Since companies do not normally hire a young engineer immediately for management positions, the first capability that must be displayed on the job is that of technical competence. Many young engineers have enrolled in Master of Science programs in order to obtain a better mastery of technical subjects, especially during the first five years after graduation. Such study programs are available under night school courses or as released-time courses during the day. Later, after technical contributions have been recognized by management and a capacity for leadership has been accepted, the young engineer's diversion in study is toward courses in business, law, public speaking, psychology, accounting, business letter writing, and economics. Many mechanical engineers have become involved in management training courses after they have been in industry from five to fifteen years.

One fact emerging from this discussion is that the educational process does not stop after engineers complete their undergraduate college studies. As with most professional people, the engineer finds that he or she must continue learning to keep abreast of technical and scientific developments or fall behind. For example, in the early days of the computer, the recent engineering graduates who had been exposed to computer studies found that they had attained a

capability in school that was lacking in engineering graduates of an earlier era.

The path towards engineering success, whether it is purely technical or along managerial lines, knows no limits. Financially, the compensation received by the individual is related to the responsibility assumed. Management hours are long and the pace is strenuous, so that those interested only in a 40-hour week and no homework should not be surprised if their superiors pass over them when management openings occur.

WHAT ABOUT FINANCIAL REWARDS?

The following three graphs are from John D. Alden, Director of Manpower Activities (as published in "The Mechanical Engineer: An In-Depth Profile" March 1975 issue of *Mechanical Engineering*). The first graph shows the annual salary and the years after graduation with a Bachelor of Science degree. In Chapter 8, the graph indicated starting salaries only for the new graduates. The rise in the starting salaries showed the effects of inflation as well as the large demand for engineers. In Fig. 9-1, however, the salaries are not only for the beginner (at the left), but also for those nearing retirement (at the right). The dollars shown on the vertical scale are for the year 1974; if inflation continues, the entire scale will be shifted upwards.

In Fig. 9-2, only the median values are shown for supervisors and the nonsupervisors. "At 5 years of experience the ratio is one supervisor to 9.7 nonsupervisors, but at 25 years of experience it is one supervisor to 1.2 nonsupervisors. Supervisory salaries thus reflect the results of promotion to positions of greater responsibility on the basis of experience, and presumably, demonstrated competence."

In Fig. 9-3, the data were broken down by degree level. "Not surprisingly, education level has a significant effect on salary. Considering all engineers in 1974, the average Master's Degree holder earned 8 percent and Doctor's Degree holders earned 25 percent more than engineers with only a Bachelor's Degree."

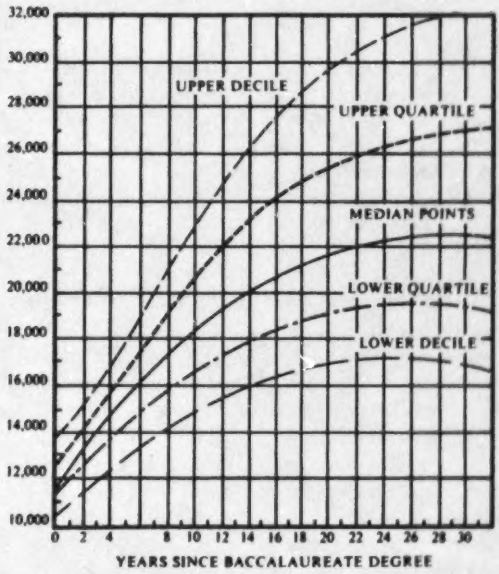
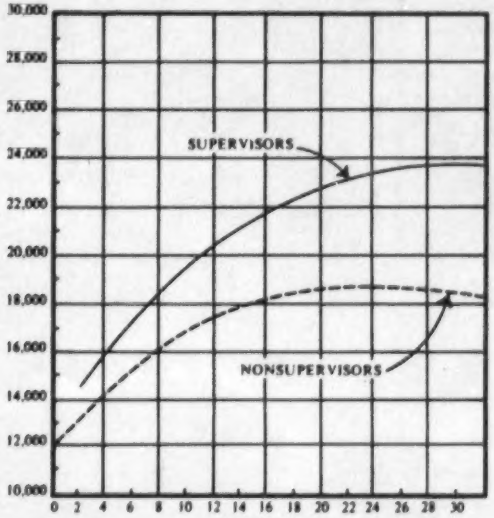


Figure 9-1. Engineers' salaries: national average.

KNOW THEM BY THE COMPANY THEY KEEP

Americans are noted for their tendency to join with others who have similar interests. In fact, one can learn much from the organizations that a professional man or woman supports with time, effort, and dues. Many of these organizations offer the engineer or scientist a place to present papers, varying from highly technical contributions to philosophic essays. Most of them have annual or semiannual conventions for presentation of papers and for conducting committee meetings. Most of them issue publications that cover such areas as new products, new processes, personalities in the news, technical

Figure 9-2. Median salaries by supervisory status.



papers, chapter news, official actions, legislation of interest, and job opportunities.

In the following list, the ECPD Societies wield a strong influence on engineering education by sending members to the schools to review programs being offered at the undergraduate level. We asked faculty members in one department to list the professional and scientific societies to which dues were being paid, and received the following astoundingly diverse list. These do not include all such societies that are flourishing in this country and abroad. They do reveal that the interests of mechanical engineers can be most diverse.

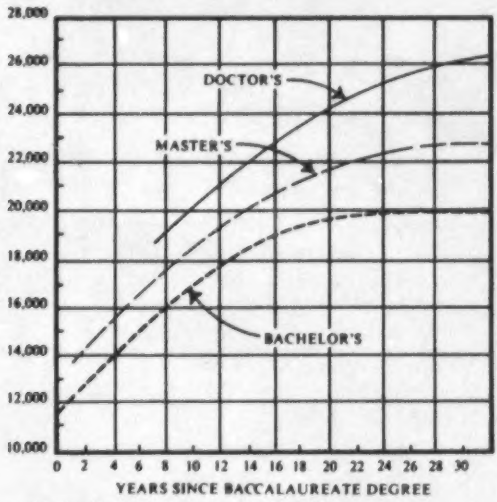


Figure 9-3. Median salaries by degree level.

SOCIETIES OF INTEREST TO ALL ENGINEERS

ECPD Societies

The following organizations are member societies of the Engineers' Council for Professional Development. Among other functions, it serves as the accrediting agency for engineering curricula.

1) American Institute of Aeronautics and Astronautics, Inc., 1290 Avenue of the Americas, New York, N.Y. 10017
2) American Institute of Chemical Engineers, 345 East 47th St., New York, N.Y. 10017
3) American Institute of Industrial Engineers, 25 Technology Park, Atlanta, Norcross, Ga. 30071
4) American Institute of Mining, Metallurgical, and Petroleum Engineers, 345 East 47th St., New York, N.Y. 10017
5) American Nuclear Society, 244 East Ogden Ave., Hinsdale, IL. 60521

6) The American Society of Agricultural Engineers, 420 Main Street, St. Joseph, MI. 49085
7) American Society of Civil Engineers, 345 East 47th St., New York, N.Y. 10017
8) American Society for Engineering Education, One Dupont Circle, Washington, D.C. 20036
9) American Society of Heating, Refrigerating, and Air-Conditioning Engineers, 345 E. 47th Street, New York, N.Y. 10017
10) The American Society of Mechanical Engineers, 345 East 47th St., New York, N.Y. 10017
11) The Institute of Electrical and Electronic Engineers, Inc., 345 East 47th St., New York, N.Y. 10017
12) National Council of Engineering Examiners, Box 752, Clemson, S.C. 29631
13) Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, Pa. 15086
14) National Institute of Ceramic Engineers, 65 Ceramic Drive, Columbus, OH 43214
15) National Society of Professional Engineers, 2029 K St. N. W., Washington, D.C. 20006
16) Society of Manufacturing Engineers, 20501 Ford Road, Dearborn, MI 48128

Honor Societies

Through academic performance mechanical engineering students can qualify for the following honor societies.

1) Pi Tau Sigma (Mechanical engineering) c/o Prof. Hudy Hewitt, M. E. Dept. Tennessee Technological University, Cookeville, Tenn. 38501
2) Sigma Xi (Research for science and engineering students) 155 Whitney Ave., New Haven, Conn. 06510
3) Tau Beta Pi (All engineering) Box 8840, University Station, Knoxville, Tenn. 37916

Professional and Scientific Societies.

The following is a partial list of professional and scientific societies to which mechanical engineers belong.

1) American Association for the Advancement of Science, 1515 Massachusetts Ave. N. W., Washington, D.C. 20005
2) Acoustical Society, 335 East 45th St., New York, N.Y. 10017
3) Air Pollution Control Association, 4400 Fifth Ave., Pittsburgh, Pa. 15213
4) American Foundrymans Society, Golf and Wolf Roads, Des Plaines, IL 60016
5) American Institute of Physics, 335 East 45th St., New York, N.Y. 10017
6) American Physical Society, 335 East 45th St., New York, N.Y. 10017
7) American Society for Cybernetics, 1130 17th St. N. W., Suite 530, Washington, D.C. 20036
8) American Society of Heating, Refrigerating, and Air-Conditioning Engineers, 345 East 47th St., New York, N.Y. 10017
9) The American Society of Mechanical Engineers, 345 E. 47th Street, New York, N.Y. 10017
10) American Society of Metals, Metals Park, Ohio. 44073
11) American Society of Military Engineers, 800 17th St. N. W., Washington, D.C. 20006
12) American Statistical Association, 806 15th St. N. W., Washington, D.C. 20005
13) American Vacuum Society, 335 East 45th St., New York, N.Y. 10017
14) Combustion Institute, 986 Union Trust Bldg., Pittsburgh, Pa. 15219
15) Operations Research Society of America, 428 E. Preston St., Baltimore, Md. 21202
16) Society of Engineering Science, c/o Prof. E. Rodin, Dept. of Applied Math., Washington Univ., St. Louis, Mo. 63130
17) Society for Experimental Stress Analysis, 21 Bridge Sq., Westport, Ct. 06880
18) Society for Computer Simulation, P.O. Box 2228, La Jolla, Ca. 92037
19) Society of Petroleum Engineers of A. I. M. E., 6200 North Central Expressway, Dallas, Tx. 75206
20) Society for Women Engineers, 345 E. 47th St., New York, N.Y. 10017

DOES THE ENGINEER HAVE A CODE OF ETHICS?

Today's high school graduate is aware of social responsibility and professional ethics because television news has exposed misdeeds of some politicians and businessmen. The professions of law and medicine have been reviewing their practices to correct some of the misdeeds of a few practitioners. Engineers, too, are greatly concerned over matters of ethical conduct and social responsibility. What is the responsibility of an engineer working for a large corporation? If a product can be unsafe under seldom-met conditions, should an engineer report this to his or her superior? If another engineer is in charge, should the assembly line be stopped? If an engineer is not in agreement with the nuclear policy of the company, should he or she quit? These are not make-believe questions, but bread-and-butter issues. Are there any rules that might help? Is this covered under professional ethics?

Some high school students and counselors have the opinion that engineers are only interested in an assigned technical task and are not even aware of ethics or social responsibility. Let us alter such views.

The Engineers' Council for Professional Development has adopted an official Code of Ethics, consisting of seven Fundamental Canons. These are lofty statements similar in intent to the Hippocratic oath of medicine. To the practicing engineer, however, the most helpful rules of conduct are offered by a supplement *Suggested Guidelines for Use with the Fundamental Canons of Ethics.* The guidelines are far too lengthy for this book, so we shall select a few samples to show the specific nature of the material.

> *3-d.* Engineers shall issue no statements, criticisms, nor arguments on engineering matters which are inspired or paid for by an interested party, or parties, unless they have prefaced their comments by explicitly identifying themselves, by disclosing the identities of the party or parties on whose behalf they are speaking, and by revealing the existence of any pecuniary interest they may have in the instant matters.
>
> *4-e.* Engineers shall not solicit nor accept gratuities,

directly or indirectly, from contractors, their agents, or other parties dealing with their clients or employers in connection with work for which they are responsible.

5-a. Engineers shall not pay nor offer to pay, either directly or indirectly, any commission, political contribution, or a gift, or other consideration in order to secure work, exclusive of securing salaried positions through employment agencies.

5-o. Engineers shall not use equipment, supplies, laboratory nor office facilities of their employers to carry on outside private practice without consent.

7-e. Engineers shall give proper credit for engineering work to those to whom credit is due, and recognize the proprietary interests of others. Whenever possible, they shall name the person or persons who may be responsible for designs, inventions, writings or other accomplishments.

There are dozens of other specific guidelines which are equally specific. In fact, every engineering graduate should be given a copy for future reference. To a high school student, such guidelines may not seem very important, but they do bring out the fact that engineers are jealous of the reputation of their profession and want to preserve the excellent record of honesty and public service. We do hope that you, too, will consider seriously a professional career in mechanical engineering.

READING MATERIAL

"Canons of Ethics for Engineers" (EC54).
Single sheet suitable for framing
($1.00)

"Suggested Guidelines for Use with the Fundamental Canons of Ethics" (EC59; 4 pp., 75 cents)

ECPD Publications
345 E. 47th Street
New York, N.Y. 10017

APPENDIX

SCHOOLS OFFERING ACCREDITED UNDERGRADUATE CURRICULA IN MECHANICAL ENGINEERING

(From 44th Annual Report of Engineers' Council for Professional Development, year ending Sept. 30, 1976)

For detailed information about a specific school and its program, write to the "Head of the Department" of the schools listed here.

Akron, University of,
Akron, Ohio. 44325
Alabama, The University of,
University, Alabama. 35486
Arizona, University of,
Tucson, Arizona. 85721
Arkansas, University of,
Fayetteville, Arkansas. 72701
Auburn University,
Auburn, Alabama. 36830
Bradley University,
Peoria, Illinois. 61625
Bridgeport, University of,
Bridgeport, Connecticut. 06602
Brigham Young University,
Provo, Utah. 84602
Brown University,
Providence, Rhode Island.
02912
Bucknell University,
Lewisburg, Pennsylvania 17837
California Polytechnic State
University, San Luis Obispo,
California 93401
California State Polytechnic
University, Pomona.
Pomona, California 91768
California State University,
Chico.
Chico, California. 95929
California State University,
Fresno.
Fresno, California. 93740
California State University,
Sacramento.
Sacramento, California. 95819
California, University of
(Berkeley).
Berkeley, California. 94720
California, University of (Davis).
Davis, California. 95616
California, University of (Santa
Barbara).
Santa Barbara, California.
93106
Carnegie-Mellon University.
Pittsburgh, Pennsylvania.
15213

Case Western Reserve University.
Cleveland, Ohio. 44106
Catholic University of America.
Washington, D.C. 20017
Christian Brothers College.
Memphis, Tennessee. 38104
Cincinnati, University of
Cincinnati, Ohio. 45221
Clarkson College of Technology
Potsdam, New York. 13676
Clemson University
Clemson, South Carolina.
29631
Cleveland State University
Cleveland, Ohio. 44115
Colorado State University
Fort Collins, Colorado. 80521
Colorado, University of
Boulder, Colorado. 80302
Columbia University
New York, New York. 10027
Connecticut, University of
Storrs, Connecticut. 06268
Cooper Union, The
New York, New York. 10003
Cornell University
Ithaca, New York. 14850
Dayton, University of
Dayton, Ohio. 45469
Delaware, University of
Newark, Delaware. 19711
Detroit, University of
Detroit, Michigan. 48221
Drexel University of
Philadelphia, Pennsylvania
19104
Duke University
Durham, North Carolina
27706
Evansville, University of
Evansville, Indiana. 47701
Fairleigh Dickinson University
Teaneck, New Jersey. 07666
Florida Institute of Technology
Melbourne, Florida. 32901
Florida, University of
Gainesville, Florida. 32611
Gannon College
Erie, Pennsylvania. 16501
George Washington University
Washington, D.C. 20052
Georgia Institute of Technology
Atlanta, Georgia. 30332
Hartford, University of
Hartford, Connecticut. 06117
Hawaii, University of
Honolulu, Hawaii. 96822
Houston, University of
Houston, Texas. 77004
Howard University
Washington, D.C. 20001
Idaho, University of
Moscow, Idaho. 83843
Illinois Institute of Technology
Chicago, Illinois. 60616
Illinois at Urbana-Champaign,
University of
Urbana, Illinois. 61801
Iowa State University
Ames, Iowa. 50010
Iowa, University of
Iowa City, Iowa. 52240
Kansas State University
Manhattan, Kansas. 66506
Kansas, University of
Lawrence, Kansas. 66045
Kentucky, University of
Lexington, Kentucky. 40506
Lafayette College
Easton, Pennsylvania. 18042
Lamar University
Beaumont, Texas. 77710
Lawrence Institute of Technology
Southfield, Michigan. 48075
Louisiana State University
Baton Rouge, Louisiana. 70803
Louisiana Tech University
Ruston, Louisiana. 71270
Louisville, University of
Louisville, Kentucky. 40208

Lowell Technological Institute
Lowell, Massachusetts. 01854
Loyola Marymount University
Los Angeles, California. 90045
Maine at Orono, University of
Orono, Maine. 04473
Manhattan College
Riverdale, New York. 10471
Marquette University
Milwaukee, Wisconsin. 53233
Maryland, University of
College Park, Maryland. 20742
Massachusetts Institute of
Technology
Cambridge, Massachusetts.
02139
Massachusetts, University of
Amherst, Massachusetts. 01002
Memphis State University
Memphis, Tennessee. 38152
Miami, University of
Coral Gables, Florida. 33124
Michigan State University
East Lansing, Michigan. 48823
Michigan Technological
University
Houghton, Michigan. 49931
Michigan-Ann Arbor, University
of
Ann Arbor, Michigan. 48104
Michigan-Dearborn, University of
Dearborn, Michigan. 48128
Minnesota, University of
Minneapolis, Minnesota. 55455
Mississippi State University
Mississippi State, Mississippi
39762
Mississippi, University of
University, Mississippi. 38677
Missouri-Columbia, University of
Columbia, Missouri. 65201
Missouri-Rolla, University of
Rolla, Missouri. 65401
Montana State University
Bozeman, Montana. 59715

Naval Postgraduate School
Monterey, California. 93940
Nebraska, University of
Lincoln, Nebraska. 68588
Nevada-Reno, University of
Reno, Nevada. 89507
New Hampshire, University of
Durham, New Hampshire.
03824
New Haven, University of
New Haven, Connecticut.
06516
New Jersey Institute of
Technology
Newark, New Jersey. 07102
New Mexico State University
Las Cruces, New Mexico.
88001
New Mexico, University of
Albuquerque, New Mexico.
87131
New York, City College of the
City University of
New York, New York. 10031
New York at Buffalo, State
University of
Buffalo, New York. 14214
New York, Polytechnic Institute
of
Brooklyn, New York. 11201
North Carolina Agricultural and
Technical State University
Greensboro, North Carolina.
27411
North Carolina State University
at Raleigh.
Raleigh, North Carolina.
27607
North Dakota State University
Fargo, North Dakota. 58102
North Dakota, University of
Grand Forks, North Dakota
58201
Northeastern University
Boston, Massachusetts. 02115

Northern Arizona University
Flagstaff, Arizona. 86001
Northrop University
Inglewood, California. 90306
Northwestern University
Evanston, Illinois. 60201
Norwich University
Northfield, Vermont. 05663
Notre Dame, University of
Notre Dame, Indiana. 46556
Ohio Northern University
Ada, Ohio. 45810
Ohio State University
Columbus, Ohio. 43210
Ohio University
Athens, Ohio. 45701
Oklahoma State University
Stillwater, Oklahoma. 74074
Oklahoma, University of
Norman, Oklahoma. 73069
Oregon State University
Corvallis, Oregon. 97331
Pennsylvania State University, The
University Park, Pennsylvania 16802
Pennsylvania, University of
Philadelphia, Pennsylvania 19174
Pittsburgh, University of
Pittsburgh, Pennsylvania 15213
Portland, University of
Portland, Oregon. 97203
Prairie View A and M University
Prairie View, Texas. 77445
Pratt Institute
Brooklyn, New York. 11205
Princeton University
Princeton, New Jersey. 08540
Puerto Rico, University of
Mayaguez, Puerto Rico. 00708
Purdue University
W. Lafayette, Indiana. 47907
Rensselaer Polytechnic Institute
Troy, New York. 12181
Rhode Island, University of
Kingston, Rhode Island. 02881
Rice University
Houston, Texas. 77001
Rochester Institute of Technology
Rochester, New York. 14623
Rochester, University of
Rochester, New York. 14627
Rose-Hulman Institute of Technology
Terre Haute, Indiana. 47803
Rutgers University-The State University of New Jersey.
New Brunswick, New Jersey. 08903
San Diego State University
San Diego, California. 92182
San Jose State University
San Jose, California. 95192
Santa Clara, University of
Santa Clara, California. 95053
Seattle University
Seattle, Washington. 98122
South Carolina, University of
Columbia, South Carolina. 29208
South Dakota School of Mines and Technology.
Rapid City, South Dakota. 57701
South Dakota State University
Brookings, South Dakota. 57006
Southeastern Massachusetts University
North Dartmouth, Massachusetts. 02747
Southern California, University of
Los Angeles, California. 90007
Southern Methodist University
Dallas, Texas. 75275
Southern University
Baton Rouge, Louisiana. 70813
Southwestern Louisiana, University of.
Lafayette, Louisiana. 70501

Stanford University
Stanford, California. 94305
Syracuse University
Syracuse, New York. 13210
Tennessee Technological University
Cookeville, Tennessee. 38501
Tennessee, University of
Knoxville, Tennessee. 37916
Texas A and M University
College Station, Texas. 77843
Texas Tech University
Lubbock, Texas. 79409
Texas at Arlington, University of
Arlington, Texas. 76010
Texas at Austin, University of
Austin, Texas. 78712
Texas at El Paso, University of
El Paso, Texas. 79968
Toledo, University of
Toledo, Ohio. 43606
Tri-State University
Angola, Indiana. 46703
Tufts University
Medford, Massachusetts. 02155
Tulane University
New Orleans, Louisiana. 70118
Tulsa, University of
Tulsa, Oklahoma. 7410
Tuskegee Institute
Tuskegee Institute, Alabama. 36088
Union College
Schenectady, New York. 12308
United States Naval Academy
Annapolis, Maryland. 21402
Utah State University
Logan, Utah. 84322
Utah, University of
Salt Lake City, Utah. 84112
Valparaiso University
Valparaiso, Indiana. 46383
Vanderbilt University
Nashville, Tennessee. 37203
Vermont, University of
Burlington, Vermont. 05401
Villanova University
Villanova, Pennsylvania. 19085
Virginia Polytechnic Institute and State University
Blacksburg, Virginia. 24061
Virginia, University of
Charlottesville, Virginia. 22901
Washington State University
Pullman, Washington. 99163
Washington, University of
Seattle, Washington. 98195
Washington University
St. Louis, Missouri. 63130
Wayne State University
Detroit, Michigan. 48202
West Virginia Institute of Technology.
Montgomery, West Virginia 25136
West Virginia University
Morgantown, West Virginia 26506
Western New England College
Springfield, Massachusetts 01119
Wichita State University
Wichita, Kansas. 67208
Wisconsin-Madison, University of
Madison, Wisconsin. 53706
Worcester Polytechnic Institute
Worcester, Massachusetts 01609
Wyoming, University of
Laramie, Wyoming. 82071
Youngstown State University
Youngstown, Ohio. 44503

Mechanical Engineering Options Within Program.
Alabama in Huntsville, University of
Huntsville, Alabama 35807

Arizona State University
Tempe, Arizona. 85281
California State University, Long Beach
Long Beach, California. 90840
Florida Technological University
Orlando, Florida. 32816
South Florida, University of
Tampa, Florida. 33602

Schools Offering Engineering Degrees But Without Concentration In Fields Such As Mechanical Engineering

Alabama in Birmingham, University of
Birmingham, Alabama. 35294
California State University, Fullerton
Fullerton, California. 92634
California State University, Los Angeles
Los Angeles, California. 90032
California State University, Northridge
Northridge, California. 91324
California, University of (Irvine)
Irvine, California 92064
California, University of (Los Angeles)
Los Angeles, California. 90024
Dartmouth College Thayer School of Engineering
Hanover, New Hampshire. 03755
Harvey Mudd College
Claremont, California. 91711
Oakland University
Rochester, Michigan. 48063
Old Dominion University
Norfolk, Virginia. 23508
San Francisco State University
San Francisco, California. 94132
Stevens Institute of Technology
Hoboken, New Jersey. 07030
Swarthmore College
Swarthmore, Pennsylvania. 19081.
Walla Walla College
College Place, Washington. 99324
Widener College
Chester, Pennsylvania. 19013

Schools Offering Degrees In Engineering Science, But Not In Mechanical Engineering.

(Other options available in all but two institutions).
California Institute of Technology.
Pasadena, California. 91125
Harvard University
Cambridge, Massachusetts. 02138
Hofstra University
Hempstead, New York. 11550
New York at Stony Brook, State University of
Stony Brook, New York. 11794
Trinity University
San Antonio, Texas. 78284
United States Air Force Academy
Colorado Springs, Colorado. 80840
Yale University
New Haven, Connecticut. 06520

Schools Not Listed Previously, And Their Accredited Programs Leading To Degrees In Engineering, That Are Related To Mechanical Engineering.

Air Force Institute of Technology
Wright-Patterson Air Force Base, Ohio. 45433
(Programs in Nuclear Eng. and Systems Eng.)

Boston University
Boston, Massachusetts. 02215
(Manufacturing Eng.)

Illinois at Chicago Circle, University of
Chicago, Illinois. 60680.
(Options in: Fluids; Mechanical Analysis and Design; and Thermomechanics and Energy Conversion).

Lehigh University
Bethlehem, Pennsylvania. 18015
(Program in: Mechanical Engineering and Mechanics.)

North Carolina at Chapel Hill, University of
Chapel Hill, North Carolina. 27514
(Environmental Engineering)

North Carolina at Charlotte, University of
Charlotte, North Carolina. 28223
(Eng. Sci, Mechanics and Materials).

Southern Illinois University at Carbondale,
Carbondale, Illinois. 62901
(Options in: Engineering Mechanics and Materials; and Thermal and Environmental).

Southern Illinois University at Edwardsville.
Edwardsville, Illinois. 62025
(Urban and Environmental Eng.)

United States Coast Guard Academy
New London, Connecticut. 06320
(Marine Engineering)

Webb Institute of Naval Architecture.
Glen Cove, New York. 11542
(Naval Architecture and Marine Eng.)

Wisconsin-Milwaukee, University of
Milwaukee, Wisconsin. 53201
(Options in: Energy; Engineering Mechanics; and Mechanical Design).